

Life Cycle Stage	Category <sup>a</sup>	Subcategory <sup>b</sup>	References
			Profile, <a href="#">EPA-HQ-OPPT-2016-0732</a> ; Public Comment, <a href="#">EPA-HQ-OPPT-2016-0732-0017</a> ; Public Comment, <a href="#">EPA-HQ-OPPT-2016-0732-0027</a>
		Aerosol cleaner	Use Document, <a href="#">EPA-HQ-OPPT-2016-0732-0003</a> ; Market Profile, <a href="#">EPA-HQ-OPPT-2016-0732</a> ; Public Comment, <a href="#">EPA-HQ-OPPT-2016-0732-0009</a>
		Non-aerosol cleaner	Use Document, <a href="#">EPA-HQ-OPPT-2016-0732-0003</a> ; Market Profile, <a href="#">EPA-HQ-OPPT-2016-0732</a> ; Public Comment, <a href="#">EPA-HQ-OPPT-2016-0732-0009</a>
	Lubricants and greases	Lubricants and greases (e.g., penetrating lubricants, cutting tool coolants, aerosol lubricants)	U.S. EPA (2016b); Market Profile, <a href="#">EPA-HQ-OPPT-2016-0732</a> ; Public Comment, <a href="#">EPA-HQ-OPPT-2016-0732-0027</a> ; Public Comment, <a href="#">EPA-HQ-OPPT-2016-0732-0029</a>
	Adhesives and sealant chemicals	Adhesives for arts and crafts	U.S. EPA (2016b); Use Document, <a href="#">EPA-HQ-OPPT-2016-0732-0003</a> ; Market Profile, <a href="#">EPA-HQ-OPPT-2016-0732</a> ; Public Comment, <a href="#">EPA-HQ-OPPT-2016-0732-0009</a>
		Light repair adhesives	U.S. EPA (2016b); Use Document, <a href="#">EPA-HQ-OPPT-2016-0732-0003</a>
	Paints and coatings	Solvent-based paints and coatings	U.S. EPA (2016b); Use Document, <a href="#">EPA-HQ-OPPT-2016-0732-0003</a> ; Market Profile, <a href="#">EPA-HQ-OPPT-2016-0732</a> ; Public Comment, <a href="#">EPA-HQ-OPPT-2016-0732-0009</a> ; Public Comment, <a href="#">EPA-HQ-OPPT-2016-0732-0020</a> ; Public Comment, <a href="#">EPA-HQ-OPPT-2016-0732-0027</a>
	Other uses	Carpet cleaning	Use Document, <a href="#">EPA-HQ-OPPT-2016-0732-0003</a> ; Market

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			Profile, <a href="#">EPA-HQ-OPPT-2016-0732</a> ; Public Comment, <a href="#">EPA-HQ-OPPT-2016-0732-0009</a>
		Laboratory chemicals	Use Document, <a href="#">EPA-HQ-OPPT-2016-0732-0003</a> ; Market Profile, <a href="#">EPA-HQ-OPPT-2016-0732</a>
		Metal (e.g., stainless steel) and stone polishes	Use Document, <a href="#">EPA-HQ-OPPT-2016-0732-0003</a> ; Market Profile, <a href="#">EPA-HQ-OPPT-2016-0732</a>
		Inks and ink removal products	Use Document, <a href="#">EPA-HQ-OPPT-2016-0732-0003</a> ; Market Profile, <a href="#">EPA-HQ-OPPT-2016-0732</a>
		Welding	Use Document, <a href="#">EPA-HQ-OPPT-2016-0732-0003</a> ; Market Profile, <a href="#">EPA-HQ-OPPT-2016-0732</a> ;
		Photographic film	Use Document, <a href="#">EPA-HQ-OPPT-2016-0732-0003</a>
		Mold cleaning, release and protectant products	Use Document, <a href="#">EPA-HQ-OPPT-2016-0732-0003</a> ; Market Profile, <a href="#">EPA-HQ-OPPT-2016-0732</a> ; Public Comment, <a href="#">EPA-HQ-OPPT-2016-0732-0017</a>
Disposal	Disposal	Industrial pre-treatment	Use Document, <a href="#">EPA-HQ-OPPT-2016-0732-0003</a>
		Industrial wastewater treatment	
		Publicly owned treatment works (POTW)	
		Underground injection	
		Municipal landfill	
		Hazardous landfill	
		Other land disposal	
		Municipal waste incinerator	
		Hazardous waste incinerator	
		Off-site waste transfer	
		Off-site waste transfer	

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<sup>a</sup> These categories of conditions of use appear in the initial life cycle diagram, reflect CDR codes and broadly represent conditions of use for perchloroethylene in industrial and/or commercial settings. <sup>b</sup> These subcategories reflect more specific uses of perchloroethylene.			

### 2.2.2.3 Overview of Conditions of Use and Lifecycle Diagram

The life cycle diagram provided in Figure 2-1 depicts the conditions of use that are considered within the scope of the risk evaluation during various life cycle stages including manufacturing, processing, distribution, use (industrial, commercial, consumer, where distinguishable) and disposal. Additions or changes to conditions of use based on additional information gathered or analyzed during problem formulation were described in Sections 2.2.2.1 and 2.2.2.2. The information is grouped according to Chemical Data Reporting (CDR) processing codes and use categories (including functional use codes for industrial uses and product categories for industrial, commercial and consumer uses), in combination with other data sources (e.g., published literature and consultation with stakeholders), to provide an overview of conditions of use. EPA notes that some subcategories of use may be grouped under multiple CDR categories.

Use categories include the following: “industrial use” means use at a site at which one or more chemicals or mixtures are manufactured (including imported) or processed. “Commercial use” means the use of a chemical or a mixture containing a chemical (including as part of an article) in a commercial enterprise providing saleable goods or services. “Consumer use” means the use of a chemical or a mixture containing a chemical (including as part of an article, such as furniture or clothing) when sold to or made available to consumers for their use (U.S. EPA, 2016a).

To understand conditions of use relative to one another and associated potential exposures under those conditions of use, the life cycle diagram includes the production volume associated with each stage of the life cycle, as reported in the 2016 CDR (U.S. EPA, 2016b), when the volume was not claimed confidential business information (CBI).

The 2016 CDR reporting data for perchloroethylene are provided in Table 2-4 from EPA’s CDR database (U.S. EPA, 2016b). This information has not changed from that provided in the scope document.

**Table 2-4. Production Volume of Perchloroethylene in CDR Reporting Period (2012 to 2015) <sup>a</sup>**

Reporting Year	2012	2013	2014	2015
Total Aggregate Production Volume (lbs)	387,623,401	391,403,540	355,305,850	324,240,744

<sup>a</sup> The CDR data for the 2016 reporting period is available via ChemView (<https://java.epa.gov/chemview>) (U.S. EPA, 2016b). The CDR data presented in the problem formulation is more specific than currently available in ChemView.

Descriptions of the industrial, commercial and consumer use categories identified from the 2016 CDR (U.S. EPA, 2016b) and included in the life cycle diagram (Figure 2-1) are summarized below. The descriptions provide a brief overview of the use category; Appendix B contains more detailed descriptions (e.g., process descriptions, worker activities, process flow diagrams, equipment illustrations) for each manufacture, processing, distribution, use and disposal category. The descriptions provided below are primarily based on the corresponding industrial function category and/or commercial and consumer product category descriptions from the 2016 CDR and can be found in EPA’s *Instructions for Reporting 2016 TSCA Chemical Data Reporting* (U.S. EPA 2016) (U.S. EPA, 2016b).

The “**Cleaning and Furniture Care Products**” category encompasses chemical substances contained in products that are used to remove dirt, grease, stains and foreign matter from furniture and furnishings or to cleanse, sanitize, bleach, scour, polish, protect or improve the appearance of surfaces (U.S. EPA,

2016a)). This category includes a wide variety of uses, including, but not limited to, the use of perchloroethylene as a commercial dry cleaning solvent, in spot cleaning formulations, in automotive care products such as brake cleaners and engine degreasers, and other aerosol and non-aerosol type cleaners.

The “**Solvents for Cleaning and Degreasing**” category encompasses chemical substances used to dissolve oils, greases and similar materials from a variety of substrates including metal surfaces, glassware and textile (U.S. EPA, 2016a). This category includes the use of perchloroethylene in vapor degreasing, cold cleaning, in industrial and commercial aerosol degreasing products and in industrial dry cleaning applications, including spot cleaning.

The “**Lubricants and Greases**” category encompasses chemical substances contained in products used to reduce friction, heat generation and wear between solid surfaces (U.S. EPA, 2016a). This category covers a variety of lubricants and greases that contain perchloroethylene including, but not limited to, penetrating lubricants, cutting tool coolants, aerosol lubricants, red greases, white lithium greases, silicone-based lubricants and chain and cable lubricants.

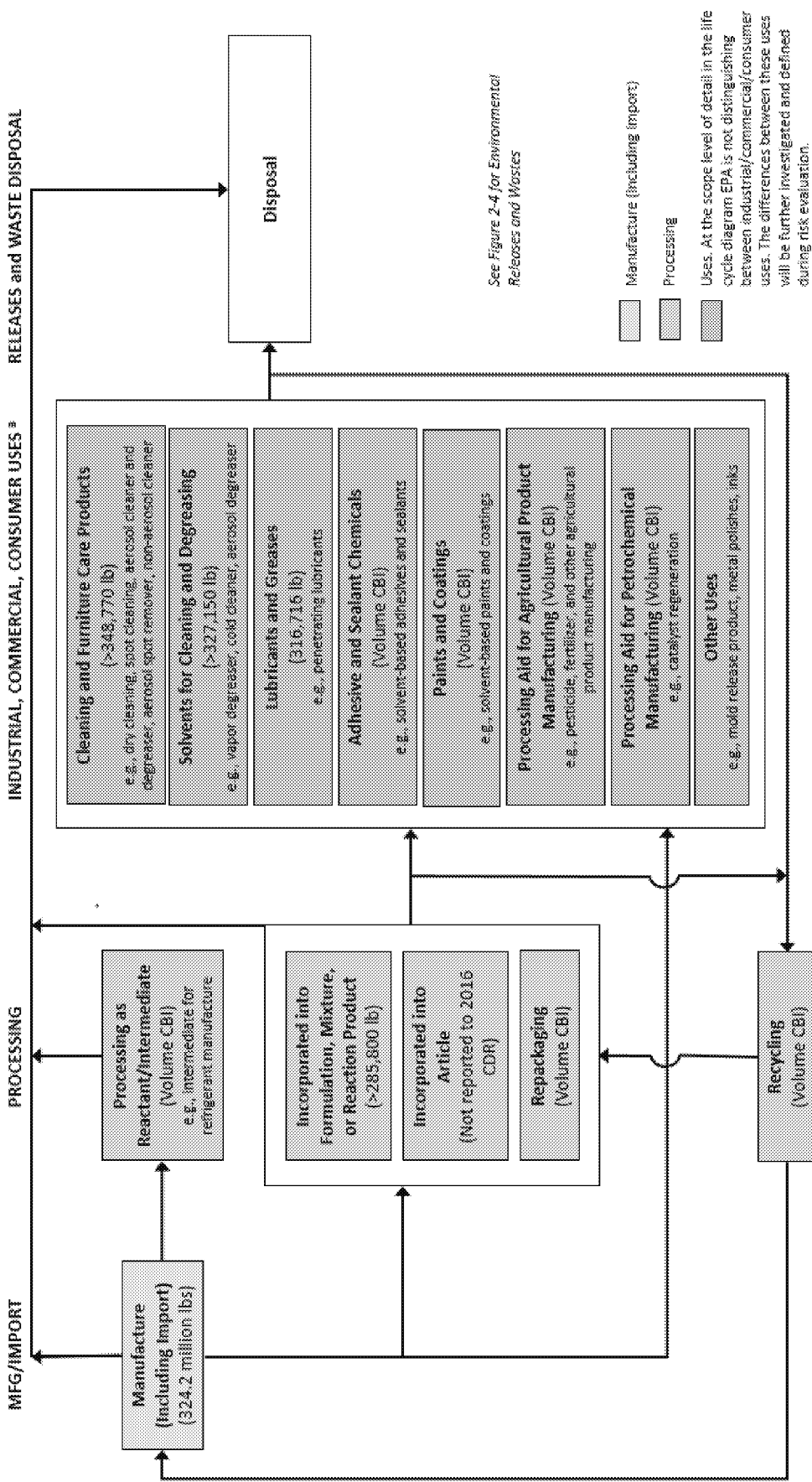
The “**Adhesives and Sealants**” category encompasses chemical substances contained in adhesive and sealant products used to fasten or bond other materials together (U.S. EPA, 2016a). EPA anticipates that the primary subcategory will be the use of perchloroethylene in solvent-based adhesives and sealants. This category covers industrial, commercial and consumer uses of adhesives and sealants.

The “**Paints and Coatings**” category encompasses chemical substances contained in paints, lacquers, varnishes and other coating products that are applied as a thin continuous layer to a surface (U.S. EPA, 2016a; OECD, 2009c). Coating may provide protection to surfaces from a variety of effects such as corrosion and UV degradation; may be purely decorative; or provide other functions (OECD, 2009c). EPA anticipates that the primary subcategory will be the use of perchloroethylene in solvent-based coatings. This category covers industrial, commercial and consumer uses of paints and coatings.

The “**Processing aids for agricultural product manufacturing**” category encompasses a variety of chemical substances that are used to improve the processing characteristics or operation of process equipment or to alter or buffer the pH of the substance (U.S. EPA, 2016a). Processing aids do not become a part of the final reaction product and are not intended to affect the function of the product (U.S. EPA, 2016a). Based on the 2016 CDR, EPA anticipates the primary subcategory will be the use in pesticide, fertilizer or other agricultural product manufacturing; however, the exact use in this subcategory has yet to be identified by EPA. Examples of processing aids include buffers, dehumidifiers, dehydrating agents, sequestering agents and chelators (U.S. EPA, 2016a).

The “**Processing aid for petrochemical manufacturing**” category is similar to the “Processing aid for agricultural product manufacturing” category except the chemicals are used specifically during the production of oil, gas and other similar products (U.S. EPA, 2016a). Based on the U.S. EPA (2016a) and a Dow Chemical Company Product Safety Assessment (Dow Chemical Co, 2008), EPA anticipates the primary subcategory will be the use of perchloroethylene for catalyst regeneration in petrochemical manufacturing.

Figure 2-1 depicts the life cycle diagram for perchloroethylene from manufacture to the point of disposal. Activities related to distribution (e.g., loading, unloading) will be considered throughout the perchloroethylene life cycle, rather than using a single distribution scenario.



**Figure 2-1. Perchloroethylene Life Cycle Diagram**

The life cycle diagram depicts the conditions of use that are within the scope of the risk evaluation during various life cycle stages including manufacturing, processing, use (industrial, commercial, consumer, where distinguishable), distribution and disposal. The production volumes shown are for reporting year 2015 from the 2016 CDR reporting period (U.S. EPA, 2016b). Activities related to distribution (e.g., loading, unloading) will be considered throughout the perchloroethylene life cycle, rather than using a single distribution scenario.

<sup>a</sup> See Table 2-3 for additional uses not mentioned specifically in this diagram.

## 2.3 Exposures

For TSCA exposure assessments, post-release pathways and routes will be described to characterize the relationship or connection between the conditions of use of perchloroethylene and the exposure to human receptors, including potentially exposed or susceptible subpopulations, and ecological receptors. EPA will take into account, where relevant, the duration, intensity (concentration), frequency and number of exposures in characterizing exposures to perchloroethylene.

### 2.3.1 Fate and Transport

Environmental fate includes both transport and transformation processes. Environmental transport is the movement of the chemical within and between environmental media. Transformation occurs through the degradation or reaction of the chemical with other species in the environment. Hence, knowledge of the environmental fate of the chemical informs the determination of the specific exposure pathways and potential human and environmental receptors EPA expects to consider in the risk evaluation. Table 2-5 provides environmental fate data that EPA identified and considered in developing the scoping and problem formulation for perchloroethylene.

Fate data including volatilization during wastewater treatment, volatilization from lakes and rivers, biodegradation rates, and organic carbon:water partition coefficient ( $\log K_{oc}$ ) were used when considering changes to the conceptual models. Model results and basic principles were used to support the fate data used in problem formulation while the literature review is currently underway through the systematic review process.

The environmental fate and transport of perchloroethylene has been assessed by WHO (2006); (ECB, 2005a). This section was prepared, in part, based on these reviews, supplemented by information from EPI Suite™ (U.S. EPA, 2012b) modules.

Based on its vapor pressure and Henry's Law constant, perchloroethylene will tend to partition from water to air and, to a lesser extent, soil to air. The persistence of perchloroethylene is highly dependent on specific environmental and microbial conditions (WHO, 2006; ECB, 2005a). In the vapor phase, perchloroethylene can be slowly transformed by reaction with hydroxyl and other radicals with half-lives of months or greater, and long-range transport may occur. In water, perchloroethylene is generally stable. Aqueous photolysis has not been observed and is not expected to be a significant degradation process. Hydrolysis, if it occurs, is expected to be slow with a half-life of greater than months to years.

Chemicals that enter wastewater treatment plants (WWTP) may be incorporated into sludge if they are not rapidly degraded or transferred into the vapor phase. Sorption to organic and inorganic solids will result in the chemical being settled out during coagulation and flocculation. EPI Suite™ (U.S. EPA, 2012b) modules were used to predict volatilization of perchloroethylene from wastewater treatment plants, lakes, and rivers and to confirm the data showing slow biodegradation. The EPI Suite™ module that estimates chemical removal in sewage treatment plants ("STP" module) was run using default settings to evaluate the potential for perchloroethylene to volatilize to air or adsorb to sludge during wastewater treatment. The STP module estimates that about 80% of perchloroethylene in wastewater will be removed by volatilization. Based on measured  $\log K_{oc} = 1.6\text{--}2.7$  perchloroethylene is not expected to sorb to a large extent but may also be settled out by entrainment and incorporation into flocs. During sludge processing perchloroethylene will tend to be transferred to air during dewatering and volume reduction processes. When biosolids (processed sludge) are land applied perchloroethylene will be transferred to air during spraying and over time by volatilization from solids and liquid phases.

Perchloroethylene in surface waters can be expected to volatilize into the atmosphere. However, perchloroethylene is denser than water and only slightly soluble in water. In soil and aquifers, it will tend to remain in the aqueous phase and be transported to ground water. Anaerobic biodegradation is expected to be a significant degradation mechanism in soil and ground water.

The EPI Suite™ module that estimates volatilization from lakes and rivers (“Volatilization” module) was run using default settings to evaluate the volatilization half-life of perchloroethylene in surface water. The parameters required for volatilization (evaporation) rate of an organic chemical from the water body to air are water depth, wind, and current velocity of the river or lake. The volatilization module estimates that the half-life of perchloroethylene in a model river will be 0.05 days and the half-life in a model lake will be 5 days.

In ground water, perchloroethylene may be present as a dense non-aqueous phase liquid (DNAPL), which, because it is denser than water, means that it will form a separate phase, often at the base of an aquifer. The half-life degradation rate in ground water is estimated to be between one to two years, based on aqueous aerobic biodegradation (Howard, 1991) but may be considerably longer under certain conditions.

**Table 2-5. Environmental Fate Characteristics of Perchloroethylene**

Property or Endpoint	Value <sup>a</sup>	References
Direct photodegradation	3 years (atmosphere)	ECB (2005a)
Indirect photodegradation	96 days (atmosphere)	ECB (2005a)
Hydrolysis half-life	Months-years	ECB (2005a)
Biodegradation	No degradation (aerobic in mixed and pure culture, modified shake flask, river die-away study, sewage inoculated).  <1 day to weeks (anaerobic, based on multiple studies).	ECB (2005a)
Bioconcentration factor (BCF)	40 and 49 (fish) 312 and 101 (marine algae)	ECB (2005a)
Bioaccumulation factor (BAF)	46 (estimated)	U.S. EPA (2012b); ECB (2005a)
Organic carbon:water partition coefficient (log K <sub>oc</sub> )	1.62.7 2.9 (estimated)	U.S. EPA (2012b); ECB (2005a)
<sup>a</sup> Measured unless otherwise noted.		

The EPI Suite™ module that predicts biodegradation rates (“BIOWIN” module) was run using default settings to estimate biodegradation rates of perchloroethylene in soil and sediment. Mixed results were obtained: four of the models built into the BIOWIN module (BIOWIN 1, 2, 5 and 6) estimate that perchloroethylene will not rapidly biodegrade in aerobic environments, while two (BIOWIN 3 and 4) estimate that perchloroethylene will rapidly biodegrade in aerobic environments. These results support the biodegradation data presented in the perchloroethylene Scope Document (U.S. EPA, 2017c), which

indicated that in soil and sediment, aerobic and anaerobic degradation can occur but is generally slow. Several microbial species have been identified that are capable of degrading perchloroethylene under certain conditions but overall biodegradation in these environments is expected to be slow with half-life of months or greater. The model that estimates anaerobic biodegradation (BIOWIN 7) predicts that perchloroethylene will degrade more rapidly under anaerobic conditions.

With BCFs and BAFs ranging from 40 to 100, ECB (2005a), WHO (2006) and ECB (2005a) indicate that there is limited potential for perchloroethylene to bioaccumulate in plants and animals.

### 2.3.2 Releases to the Environment

Releases to the environment from conditions of use (e.g., industrial and commercial processes, commercial or consumer uses resulting in down-the-drain releases) are one component of potential exposure and may be derived from reported data that are obtained through direct measurement, calculations based on empirical data and/or assumptions and models.

A source of information that EPA considered in evaluating exposure are data reported under the Toxics Release Inventory (TRI) program. Under the Emergency Planning and Community Right-to-Know Act (EPCRA) Section 313 rule, perchloroethylene is a TRI-reportable substance effective January 1, 1987. During problem formulation, EPA further analyzed the TRI data and examined the definitions of elements in the TRI data to determine the level of confidence that a release would result from certain types of disposal to land (e.g., RCRA Subtitle C hazardous landfill and Class I underground Injection wells) and incineration. EPA also examined how perchloroethylene is treated at industrial facilities.

Table 2-6 provides production-related waste managed data (also referred to as waste managed) for perchloroethylene reported by industrial facilities to the TRI program for 2015. Table 2-7 provides more detailed information on the quantities released to air or water or disposed of on land.

**Table 2-6. Summary of Perchloroethylene TRI Production-Related Waste Managed in 2015 (lbs)**

Number of Facilities	Recycling	Energy Recovery	Treatment	Releases <sup>a, b, c</sup>	Total Production Related Waste
27	46,406,761	2,341,981	15,132,768	1,177,484	65,058,994
Data source: 2015 TRI Data [updated March 2017 (U.S. EPA, 2017f)] <sup>(cvi)</sup> . <sup>a</sup> Terminology used in these columns may not match the more detailed data element names used in the TRI public data and analysis access points. <sup>b</sup> Does not include releases due to one-time event not associated with production such as remedial actions or earthquakes. <sup>c</sup> Counts all releases including release quantities transferred and release quantities disposed of by a receiving facility reporting to TRI.					

In 2015, 27 facilities reported a total of 65 million pounds of perchloroethylene waste managed. Of this total, roughly 46 million pounds were recycled, 2.3 million pounds were recovered for energy, 15 million pounds were treated and 1.18 million pounds were released into the environment.

Release quantities in Table 2-7 are more representative of actual releases during the year. Production-related waste managed shown in Table 2-6 excludes any quantities reported as catastrophic or one-time releases (TRI Section 8 data), while release quantities shown in Table 2-7 include both production-related and non-routine quantities (TRI Section 5 and 6 data). Table 2-6 counts all release quantities reported to TRI while Table 2-7 counts releases once at final disposition, accounting for transfers of chemical waste from one TRI reporting facility and received by another TRI reporting facility for final

disposal. As a result, release quantities may differ slightly and may further reflect differences in TRI calculation methods for reported release range estimates (U.S. EPA, 2017e).

**Table 2-7. Summary of Perchloroethylene TRI Releases to the Environment in 2015 (lbs)**

	Number of Facilities	Air Releases		Water Releases	Land Releases			Other Releases <sup>a</sup>	Total Releases <sup>b, c</sup>
		Stack Air Releases	Fugitive Air Releases		Class I Under-ground Injection	RCRA Subtitle C Landfills	All other Land Disposal <sup>a</sup>		
Subtotal		435,558	279,073		272	78,121	414		
Totals	27	714,631		10,393	78,807			373,653	1,177,484

Data source: 2015 TRI Data [updated March 2017] (U.S. EPA, 2017e) [Table 2-7].

<sup>a</sup> Terminology used in these columns may not match the more detailed data element names used in the TRI public data and analysis access points.

<sup>b</sup> These release quantities do include releases due to one-time events not associated with production such as remedial actions or earthquakes.

<sup>c</sup> Counts release quantities once at final disposition, accounting for transfers to other TRI reporting facilities that ultimately dispose of the chemical waste.

While production-related waste managed shown in Table 2-6 excludes any quantities reported as catastrophic or one-time releases (TRI Section 8 data), release quantities shown in Table 2-7 include both production-related and non-routine quantities (TRI Section 5 and 6 data). As a result, release quantities may differ slightly and may further reflect differences in TRI calculation methods for reported release range estimates (U.S. EPA, 2017e).

Table 2-8 provides an additional representation of TRI data including the volume of perchloroethylene sent to each release, disposal, and waste treatment method.

**Table 2-8. Summary of 2015 TRI Releases for Perchloroethylene (CASRN 127-18-4)**

Waste Type	Conceptual Model Release Category	TRI Category	Volume from TRI (lbs)	Number of Reporting Sites from TRI	% of Total Production Related Waste Managed
Wastewater or Liquid Wastes	Industrial Pre-Treatment (indirect discharge)	POTW	857	15	<0.001%
	Industrial WWT (indirect discharge)	Off-site WWT (non-POTW)	9,187	5	<0.001%
	Industrial WWT (direct discharge)	Water	349	19	<0.001%
	Underground Injection	Class I Underground Injection	271	6	<0.001%
Solid Wastes and Liquid Wastes	Hazardous and Municipal Waste Landfill	RCRA Subtitle C Landfill	78,120	20	0.12%
		Other Landfills, Land Treatment, and Disposal	413	19	<0.001%
	Hazardous and Municipal Waste Incinerators, Recycling and Other Treatment	Off-site Incineration	1,098,035	65	1.7%
		Energy Recovery	2,341,981	44	3.6%
		Other Treatment and Management Methods	269,529	19	0.41%
		Transfers to Waste Broker	138,052	16	0.21%
		Recycling	46,406,761	51	71.3%
		Unspecified Treatment Methods <sup>2</sup>	14,000,805	44	21.5%
Emissions to Air	Emissions to Air	Fugitive Air <sup>1</sup>	279,073	152	0.43%
		Stack Air <sup>1</sup>	435,558	119	0.70%
Total Production Related Waste Managed			65,067,293	219	
Total One-Time Release Waste			31,082	6	<0.001%
Total Waste Managed			65,098,375	219	

<sup>2</sup> Because sites such as treatment, storage, and disposal facilities (TSDFs) are required to report to TRI, the total volumes for these categories may include volumes reported as transferred to off-site treatment, such as off-site incineration.

### ***Releases to Air***

TRI data in Table 2-8 show air as a primary medium of environmental release. These releases include both fugitive air emissions and point source (stack) air emissions. Fugitive air emissions (totaling 279,073 pounds from 2015 TRI data) are emissions that do not occur through a confined air stream, which may include equipment leaks, releases from building ventilation systems, and evaporative losses from surface impoundments and spills. Point source (stack) air emissions (totaling 435,558 pounds from TRI reporting year 2015 data) are releases to air that occur through confined air streams, such as stacks, ducts or pipes.

### ***Releases to Water***

In the 2015 TRI, 349 lbs of perchloroethylene were reported as directly released to surface water discharge, 857 lbs were sent to POTWs, and 9,187 lbs were sent to off-site non-POTW wastewater treatment.

### ***Releases to Land***

As shown in Table 2-8, TRI reports approximately 78,000 pounds transferred to RCRA Subtitle C landfills. EPA will not further analyze releases to hazardous waste landfills because these types of landfill mitigate exposure to the wastes. TRI also reports approximately 414 pounds transferred to other land disposal methods. As discussed in Section 2.3.5.3, perchloroethylene will not appreciably bind to sediment, soil or biosolids.

### ***Incineration***

During problem formulation, EPA reviewed air emissions from on-site incineration and energy recovery. Air emissions resulting from these operations are already included in the TRI reports and will be used in the analysis of air releases.

## **2.3.3 Presence in the Environment and Biota**

Monitoring studies or a collection of relevant and reliable monitoring studies provide(s) information that can be used in an exposure assessment. Monitoring studies that measure environmental concentrations or concentrations of chemical substances in biota provide evidence of exposure. Monitoring and biomonitoring data were identified in EPA's data search for perchloroethylene:

### ***Environment***

Perchloroethylene has been found in air, soil, surface water, salt water, drinking water, aquatic organisms and terrestrial organisms (WHO, 2006). Historic industrial, commercial and military use of perchloroethylene, including unregulated or improper disposal of perchloroethylene wastes, has resulted in location-specific soil and ground water contamination. Perchloroethylene is a common ground water contaminant at hazardous waste sites in the U.S. (ATSDR, 2014) and a common drinking water contaminant (U.S. EPA, 2016b). EPA will analyze manufacturing, processing, distribution, use, disposal and recycling to identify and characterize current sources of release and contamination.

Urban and industrial areas are prone to higher perchloroethylene air concentrations than rural areas due to the concentration of sources (ATSDR, 2014; U.S. EPA, 2012e; WHO, 2006). EPA air monitoring data from 2013 reported detection of perchloroethylene in 77% of ambient air samples, with 58% of detects above the method detection limit (U.S. EPA, 2015a)(Table 4.1). Indoor air concentrations of perchloroethylene tend to be greater than concentrations in outdoor air (ATSDR, 2014; U.S. EPA, 2012e).

Perchloroethylene is a common contaminant in municipal drinking water supplies and ground water, with some of the highest measured concentrations in ground water occurring near perchloroethylene contaminated sites (for some examples, see (ATSDR, 2014; WHO, 2006) and references therein). EPA and the USGS National Water Quality Assessment Program (Cycle 1, 1992-2001) reported perchloroethylene contamination in U.S. surface water and ground water in 19.6% of samples (n=5,911) and at 13.2% of sites (n=4,295), with detection in surface water occurring more frequently than in ground water (U.S. EPA, 2009). EPA's Second Six-Year Review Contaminant Occurrence Data reported occurrence of monitored chemicals in U.S. drinking water supplies from 1998 to 2005. The Second Six-Year Review data showed perchloroethylene occurrence in 2.5% of roughly 50,000 public water systems, with thirty-six states reporting drinking water systems with at least one detection above the maximum contaminant level (MCL: 5 µg/L) (U.S. EPA, 2009).

### ***Air***

Urban and industrial areas are prone to higher perchloroethylene air concentrations than rural areas due to the concentration of sources (ATSDR, 2014; U.S. EPA, 2012e; WHO, 2006). Monitoring data (measured) from EPA's Air Quality System (AQS) and the open literature, as well as modeled estimates based on the National Air Toxics Assessment (NATA) and TRI emissions data suggest that perchloroethylene (tetrachloroethylene) is present in ambient air. The 2011 NATA analysis indicates perchloroethylene concentrations range from non-detect to 5.07 µg/m<sup>3</sup>, with a mean 0.1 µg/m<sup>3</sup>. EPA air monitoring data from 2013 reported detection of perchloroethylene in 77% of ambient air samples, with 58% of detects above the method detection limit (U.S. EPA, 2015a) (Table 4.1). The EPA Report on the Environment (U.S. EPA, 2017a) evaluated perchloroethylene concentrations from ambient air monitoring data, 2003-2013, and demonstrated that the annual average perchloroethylene air concentration is decreasing over time, from 0.429 µg/m<sup>3</sup> to 0.115 µg/m<sup>3</sup> (<https://cfpub.epa.gov/roe/index.cfm>).

Indoor air concentrations of perchloroethylene tend to be greater than concentrations in outdoor air (ATSDR, 2014; U.S. EPA, 2012e). In a multi-city study that evaluated the relationship between indoor and outdoor air pollutant concentrations, perchloroethylene was measured in 44.3% of 555 homes in three US cities (Weisel et al., 2005). In this study, the median concentration was 0.56 µg/m<sup>3</sup> and the 99<sup>th</sup> percentile was 20.9 µg/m<sup>3</sup>. The median indoor air level of perchloroethylene in about 400 Dutch homes was 4 µg/m<sup>3</sup>, while maximum levels varied between 49 and 205 µg/m<sup>3</sup>. Levels can be much higher in buildings housing dry cleaning facilities. For example, sampling (over 100 samples) of air in six residential apartments in two buildings where dry cleaning was carried out on the ground floor revealed tetrachloroethene concentrations ranging from 50 to 6100 µg/m<sup>3</sup>, with means ranging from 358 to 2408 µg/m<sup>3</sup> (ECB, 2005a).

### ***Surface Water***

Discharge Monitoring data (measured) were reported in EPA's Discharge Monitoring Report (DMR) Pollutant Loading Tool ([https://cfpub.epa.gov/dmr/ez\\_search.cfm](https://cfpub.epa.gov/dmr/ez_search.cfm)). The tool uses discharge monitoring report (DMR) data from ICIS-NPDES to calculate pollutant discharge amounts. This tool includes the top facility discharges for 2017. This information was used as a screening tool to evaluate some preliminary drinking concentrations. Using this tool an average concentration from the top discharger (total of 70 samples) would be 0.019 mg/L (19 ug/L) and the average maximum concentration for discharge would be 0.05 mg/L (50 ug/L). Note that this would only report the discharge to stream based on permits and would not report the actual stream concentrations. Reporting discharge would likely overestimate the actual stream concentrations.

A search was done through the European IPChem database which is a single access point for locating and retrieving chemical surface water monitoring data collections (<https://ec.europa.eu/jrc/en/event/conference/ipchem>). Using this tool, an average concentration from the top dischargers (total of 20 samples) in surface water was 0.0058 mg/L (5.8 ug/L) and the average of the maximum concentration for 20 dischargers would be 0.0089 mg/L (8.9 ug/L) with >1000 samples collected indicating that ICIS-NPDES discharges would result in an overestimate to actual stream concentrations.

According to WHO (2006), perchloroethylene has been measured in surface (river) waters in Germany, Finland, the Netherlands, Italy, France, Switzerland, the United Kingdom, and the USA. Concentrations ranged from 0.01 to 168 µg/l, with levels typically below 5 µg/l.

### ***Groundwater***

Although groundwater can be higher than concentrations in surface water, this could reflect the fact that groundwater measurements tend to be taken where a problem (e.g. a spill) is thought to exist. Groundwater levels are usually below 10 µg/l, but concentrations as high as 1300 µg/l have been reported for a legacy contaminated site. Historic industrial, commercial, and military use of perchloroethylene, including unregulated or improper disposal of perchloroethylene wastes are considered legacy uses, but have resulted in location-specific soil and groundwater contamination (ECB, 2005a).

### ***Sediment***

Perchloroethylene is not likely to be in the sediment based on its physical and chemical properties. Nevertheless, perchloroethylene has been measured in sediment samples at 1–50 µg/kg wet weight in Germany and at <5 µg/kg wet weight in the USA (WHO, 2006). A search was done through the European IPChem database. Using this tool, an average sediment concentration (from only 12 samples collected) was <15 µg/kg.

### ***Soil***

According to ECB (2005a), volatilization of perchloroethylene from dry soil is likely to be rapid due to its high vapor pressure and low adsorption to soil.

### ***Biota***

The EU Risk Assessment Report (ECB, 2005a) summarized data on measured levels of perchloroethylene in biota, including algae, invertebrates, fish and terrestrial plants. Nearly all reported concentrations are from locations in the EU and are below ~25 µg/kg.

### ***Biomonitoring***

Perchloroethylene has been measured in biomonitoring samples of U.S. populations. A subset of National Health and Nutrition Examination Survey (NHANES) data (1999-2000) reported in Lin et al. (2008) show the presence of perchloroethylene in 77% of human blood samples from non-smoking U.S. adults. Updated biomonitoring data reported by the Centers for Disease Control (CDC), sampled between 2001 and 2008, show a possible decline in the prevalence of perchloroethylene in U.S. population human blood samples, however limits of detection differ between the two data sets, complicating direct comparison. The CDC data show a decreasing concentration trend over the timeframe of data collection (CDC, 2017).

### **2.3.4 Environmental Exposures**

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The manufacturing, processing, use and disposal of perchloroethylene can result in releases to the environment. In this section, EPA presents exposures to aquatic and terrestrial organisms.

#### ***Aquatic Environmental Exposures***

EPA identified and reviewed national scale monitoring data to support this problem formulation. EPA and the USGS National Water Quality Assessment Program (Cycle 1, 1992-2001) reported perchloroethylene contamination in U.S. surface water and ground water in 19.6% of samples (n=5,911) and at 13.2% of sites (n=4,295), with detection in surface water occurring more frequently than in ground water (U.S. EPA, 2009). More recently measured, national-scale monitoring data was from EPA's STOrage and RETreival (STORET) and National Water Information System (NWIS). Based on STORET query for perchloroethylene for the past ten years, perchloroethylene is detected in surface water in the United States. The data showed a detection rate (above quantification limit and/or above reporting limit) of approximately 15% for surface water, with detections ranging from 0.02 µg/L to 26.7 µg/L.

#### ***Terrestrial Environmental Exposures***

Terrestrial species populations living near industrial and commercial facilities using perchloroethylene may be exposed via multiple routes such as ingestion of surface waters and inhalation of outdoor air. As described in Section 2.3.3, perchloroethylene is present and measurable through monitoring in a variety of environmental media including ambient and indoor air, surface water and ground water.

### **2.3.5 Human Exposures**

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In this section EPA presents occupational, consumer exposures and general population exposures. Subpopulations, including potentially exposed and susceptible subpopulations, within these exposure categories are also presented.

#### **2.3.5.1 Occupational Exposures**

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Exposure pathways and exposure routes are listed below for worker activities under the various conditions of use (industrial or commercial) described in Section 2.2. In addition, exposures to occupational non-users (ONU) who do not directly handle the chemical but perform work in an area where the chemical is present are listed. Engineering controls and/or personal protective equipment may impact occupational exposure levels.

Workers and occupational non-users may be exposed to perchloroethylene when performing activities associated with the conditions of use described in Section 2.2, including, but not limited to:

- Unloading and transferring perchloroethylene to and from storage containers to process vessels;
- Handling, transporting and disposing of waste containing perchloroethylene;
- Using perchloroethylene in process equipment (e.g., vapor degreasing machine);
- Cleaning and maintaining equipment;
- Sampling chemicals, formulations or products containing perchloroethylene for quality control;
- Repackaging chemicals, formulations or products containing perchloroethylene;
- Applying formulations and products containing perchloroethylene onto substrates (e.g., spray applying coatings or adhesives containing perchloroethylene);
- Use in dry cleaning processes; and
- Performing other work activities in or near areas where perchloroethylene is used.

During problem formulation, EPA further analyzed the expected physical form, associated exposure route, and exposure pathway for each condition of use.

### ***Key Data***

Key data that inform occupational exposure assessment include: the OSHA Chemical Exposure Health Data (CEHD) and NIOSH Health Hazard Evaluation (HHE) Program data. OSHA data are workplace monitoring data from OSHA inspections. The inspections can be random or targeted or can be the result of a worker complaint. OSHA data can be obtained through the OSHA Occupational Safety and Health Information System (OIS) at <https://ois.osha.gov/portal/server.pt> Appendix B includes a summary of perchloroethylene personal monitoring air samples obtained from OSHA inspections conducted between 2011 and 2016. NIOSH HHEs are conducted at the request of employees, union officials or employers and help inform potential hazards at the workplace. HHEs can be downloaded at <https://www.cdc.gov/niosh/hhe/>. HHE will be considered during risk evaluation.

### ***Inhalation***

Based on these occupational exposure scenarios, inhalation exposure to vapor is expected. EPA anticipates this is the most important perchloroethylene exposure pathway for workers and occupational nonusers based on the high volatility of perchloroethylene. Based on the potential for spray application of some products containing perchloroethylene exposures to mists are also expected for workers and ONU and will be incorporated into the occupational inhalation exposure estimates.

The United States has several regulatory and non-regulatory exposure limits for perchloroethylene: An OSHA Permissible Exposure Limit (PEL) of 100 ppm (685 mg/m<sup>3</sup>), the ceiling is 200 ppm and the peak for a single time period up to 5 minutes for any 3 hours is 300 ppm, based on central nervous system effects, eye and skin irritation and liver and kidney damage.(OSHA, 1997) and an American Conference of Government Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) of 25 ppm 8-hour TWA (ACGIH, 2001). A NIOSH Recommended Exposure Limit (REL) has not been established, but California has set its PEL at 25 ppm (170 mg/m<sup>3</sup>) as a time weighted average, 100 ppm (685 mg/m<sup>3</sup>) as a short term exposure limit (STEL) and 300 ppm as a ceiling.

The influence of these exposure limits on occupational exposures will be considered in the occupational exposure assessment. Also, the National Institute for Occupational Safety and Health (NIOSH) indicates that perchloroethylene has an immediately dangerous to life and health (IDLH) value of 150 ppm based on effects that might occur from a 20-30-minute exposure, and NIOSH provides a notation that perchloroethylene is a potential occupational carcinogen (NIOSH, 1994a).

### ***Dermal***

Based on the conditions of use, EPA expects dermal exposures for workers who have skin contact with liquids and vapors. Occupational non-users are not directly handling perchloroethylene; therefore, skin contact with liquid perchloroethylene is not expected for occupational non-users but skin contact with vapors is expected for occupational nonusers.

#### **2.3.5.2 Consumer Exposures**

Perchloroethylene can be found in consumer and/or commercial products that are readily available for public purchase at common retailers ([EPA-HQ-OPPT-2016-0732-0003](#), Sections 3 and 4 and Table 2-3) and can therefore result in exposures to consumers and bystanders (non-product users that are incidentally exposed to the product). The magnitude of exposure will depend upon the concentration of perchloroethylene products, use patterns (including frequency, duration, amount of product used, room of use) and application methods. Several consumer products need to be analyzed including solvents for

cleaning and degreasing, lubricants and greases, adhesives and sealant chemicals, paints and coatings, cleaning and furniture care products, and other uses such as mold release products, metal polishes and inks. Application activities include using aerosol and non-aerosol spraying, wiping, and painting. Other activities include mixing, pouring, and placing various types of liquids, slurries and pastes. Information regarding use patterns and application methods will be needed to build exposure scenarios. Any products which are spray applied are likely to result in some level of inhalation exposure to the consumer user and bystander in the room of use. Products used in the liquid form are also likely to result in some level of inhalation exposure to the consumer given the high vapor pressure of perchloroethylene. Consumer exposures are expected to be acute in nature, however, there may be a subset of consumers who use products on a frequent or regular basis resulting in sub-chronic or chronic exposures.

Although perchloroethylene is a liquid at room temperature, it has a high vapor pressure and tends to volatilize to air. It should be noted that the nature of the consumer solvent (whether the solvent has a high vapor pressure) and the overall percentage of perchloroethylene in the mixture may either increase or decrease the evaporation rates. Consumer products formulated with a high vapor pressure solvent and have high weight fraction of perchloroethylene will vaporize at a faster rate. The nature of the solvent and weight fraction will influence the exposure pathway.

### ***Inhalation***

EPA expects that inhalation exposure to vapor will be the primary route of exposure for consumer users of perchloroethylene containing products. The magnitude of exposure will depend upon the concentration of perchloroethylene in products, use patterns (including frequency, duration, amount of product used, room of use) and application methods. Several product types and scenarios will be analyzed including spray adhesives, spray degreasers (engine cleaning and electronics cleaning), and aerosol spot removers. Information regarding use patterns and application methods will be needed to build exposure scenarios for other products identified during scoping (e.g., liquid cleaners, adhesive accelerants, building and construction materials, cutting oils). Any products which are spray applied are likely to result in some level of inhalation exposure to the consumer user and also to a bystander in the room of use. Products used in the liquid form are also likely to result in some level of inhalation exposure to the consumer given the high vapor pressure of perchloroethylene. Consumer exposures are expected to be acute in nature, however, there may be a subset of consumers who use products on a frequent or regular basis resulting in sub-chronic or chronic exposures.

Exposures routes for consumers using perchloroethylene-containing products primarily include direct inhalation of vapors, mists and aerosols (e.g., aerosols from spray applications), indirect inhalation exposures after application and dermal exposure to products. Bystanders may be exposed through inhalation of vapors and mists that deposit in the upper respiratory tract; EPA assumes mists will be absorbed via inhalation.

### ***Dermal***

There is the potential for dermal exposures to perchloroethylene in consumer uses. Exposure to perchloroethylene may also occur via dermal contact with dry-cleaned fabrics or other articles treated with products containing perchloroethylene (U.S. EPA, 2012e). Perchloroethylene is absorbed dermally, and potential exposures will depend on exposure characteristics such as skin surface area, product volume and exposure duration. The potential for dermal absorption is limited based on high vapor pressure, and perchloroethylene is expected to volatilize quickly from surfaces (see Section 2.5.2). However, the nature of the product or article containing perchloroethylene, chemical loading, other

components present in product mixtures and the weight fraction of perchloroethylene in the product will affect dermal absorption.

### ***Oral***

Consumers may be exposed to perchloroethylene via transfer of chemical from hand to mouth. However, this exposure pathway is expected to be limited by a combination of dermal absorption and volatilization of perchloroethylene from skin. Due to the expected very low magnitude of accidental hand to mouth exposure, EPA does not plan to further assess this pathway.

### ***Exposures from Disposal***

EPA does not expect exposure to consumers from disposal of consumer products. It is anticipated that most products will be disposed of in original containers, particularly those products that are purchased as aerosol cans.

## **2.3.5.3 General Population Exposures**

Wastewater/liquid wastes, solid wastes or air emissions of perchloroethylene could result in potential pathways for oral, dermal or inhalation exposure to the general population.

### ***Inhalation***

General population inhalation exposure to perchloroethylene in air may result from industrial manufacturing and processing plant fugitive and stack emissions. Perchloroethylene volatilizes from contaminated soil and shallow ground water, possibly resulting in elevated outdoor inhalation exposure. Through a process known as vapor intrusion, volatilized perchloroethylene may also infiltrate residential and commercial buildings through cracks in floors, crawl spaces, pipe fittings and toilet and sewer junctions, leading to elevated indoor concentrations of perchloroethylene and greater inhalation exposure (ATSDR, 2014; U.S. EPA, 2012f). In addition, inhalation exposures to perchloroethylene may occur due to volatilization of perchloroethylene from contaminated water (municipal or well water) during showering and bathing (U.S. EPA, 2012e).

Families of workers with occupational perchloroethylene exposure are exposed secondarily by perchloroethylene volatilization from workers clothing, and from exhaled breath, as un-metabolized perchloroethylene is exhaled on the breath as the primary excretion mechanism in humans (ATSDR, 2014; U.S. EPA, 2012e).

Indoor emissions, from the use of perchloroethylene containing products and articles (e.g., degreasers; recently dry-cleaned clothing), may also be sources of perchloroethylene in indoor air (ATSDR, 2014; U.S. EPA, 2012e).

### ***Oral***

The general population may ingest perchloroethylene via contaminated drinking water, ground water and/or surface water (ATSDR, 2014; U.S. EPA, 2012e). Perchloroethylene enters water supplies through industrial and commercial wastewater and liquid waste streams, sewage sludge land application, wet deposition (rain) and leaching from contaminated soils (U.S. EPA, 2009). Oral ingestion pathways may include exposure to contaminated drinking water or breast milk, or incidental ingestion of contaminated water while swimming or bathing. Infants and young children may also be exposed to perchloroethylene via mouthing of treated products and articles (e.g., spot treatment of carpets; dry cleaned blanket).

The EU Risk Assessment Report (ECB, 2005a) indicates that perchloroethylene may be present in fish, although EPA does not anticipate fish ingestion to be a significant general population exposure pathway, as perchloroethylene has a low bioaccumulation potential in aquatic organisms (BCF 40 50', Kow < 3)(WHO, 2006).

### ***Dermal***

General population dermal exposure to perchloroethylene is possible from showering, bathing and swimming in contaminated water (U.S. EPA, 2012e). Perchloroethylene is absorbed dermally, and potential exposures will depend on exposure characteristics such as skin surface area, exposure media concentration and exposure duration. The potential for dermal absorption is limited based on high vapor pressure, and perchloroethylene is expected to volatilize quickly from surfaces (see Section 2.5.2). However, the nature of the environmental media containing perchloroethylene and chemical loading will affect dermal absorption.

### **2.3.5.4 Potentially Exposed or Susceptible Subpopulations**

TSCA requires the determination of whether a chemical substance presents an unreasonable risk to “a potentially exposed or susceptible subpopulation identified as relevant to the risk evaluation” by EPA. TSCA § 3(12) states that “the term ‘potentially exposed or susceptible subpopulation’ means a group of individuals within the general population identified by the Administrator who, due to either greater susceptibility or greater exposure, may be at greater risk than the general population of adverse health effects from exposure to a chemical substance or mixture, such as infants, children, pregnant women, workers, or the elderly.” General population is “the total of individuals inhabiting an area or making up a whole group” and refers here to the U.S. general population (U.S. EPA, 2011).

As part of the Problem Formulation, EPA identified potentially exposed and susceptible subpopulations for further analysis during the development and refinement of the life cycle, conceptual models, exposure scenarios, and analysis plan. In this section, EPA addresses the potentially exposed or susceptible subpopulations identified as relevant based on greater exposure. EPA will address the subpopulations identified as relevant based on greater susceptibility in the hazard section.

EPA identifies the following as potentially exposed or susceptible subpopulations that EPA plans to analyze in the risk evaluation due to their *greater exposure*:

- Workers and occupational non-users.
- Consumers and bystanders associated with consumer use. Perchloroethylene has been identified in products available to consumers; however, only some individuals within the general population may use these products. Therefore, those who do use these products are a potentially exposed or susceptible subpopulation due to greater exposure.
- Other groups of individuals within the general population who may experience greater exposures due to their proximity to conditions of use identified in Section 2.2 that result in releases to the environment and subsequent exposures (e.g., individuals who live or work near manufacturing, processing, distribution or use sites).

Perchloroethylene is lipophilic, and accumulates in fatty fluids and tissues in the human body. Subpopulations that may have higher body fat composition, and may be more highly exposed include pubescent and adult women, including women of child-bearing age. The EPA IRIS Assessment for perchloroethylene (U.S. EPA, 2012e) also identified the developing fetus as potentially exposed, as well as infants consuming breastmilk, particularly for mothers with occupational exposure to

perchloroethylene or exposure due to proximity to industrial or commercial sources (U.S. EPA, 2012e). Infants fed by formula may also experience increased perchloroethylene exposure if perchloroethylene is present in drinking water supplies (U.S. EPA, 2012e).

In developing exposure scenarios, EPA will analyze available data to ascertain whether some human receptor groups may be exposed via exposure pathways that may be distinct to a particular subpopulation or lifestage and whether some human receptor groups may have higher exposure via identified pathways of exposure due to unique characteristics (e.g., activities, duration or location of exposure) when compared with the general population (U.S. EPA, 2006b).

The behavior of children may put them in closer contact with some sources of perchloroethylene, such as carpet cleaners. Children may be exposed via inhalation as bystanders, during consumer use in the home. Children tend to consume more water and food per body weight relative to adults, and have greater skin surface area and skin permeability than adults, relative to weight, which can result in proportionally higher ingestion and dermal exposures. Children's exposure to perchloroethylene via ingestion of contaminated food is likely to be low. Perchloroethylene has low bioaccumulation potential and, if present, would have low concentrations in fish or seafood. The half-life of perchloroethylene in soil is short, and is unlikely to be found in food crops. Perchloroethylene has been measured in fatty foods (butter, oils and meats) when stored in proximity to indoor perchloroethylene sources (U.S. EPA, 2012d). Drinking water could be a significant source of perchloroethylene ingestion exposure for children, who drink roughly four times as much water as adults (U.S. EPA, 2011).

EPA will continue to analyze available data to ascertain whether some human receptor groups may be exposed via pathways that may be distinct to a particular subpopulation or lifestage (e.g., children's crawling, mouthing or hand-to-mouth behaviors).

In summary, in the risk evaluation for perchloroethylene, EPA expects to analyze the following potentially exposed groups of human receptors: workers, occupational non-users, consumers, bystanders associated with consumer use, and other groups of individuals within the general population who may experience greater exposure. EPA may also identify additional potentially exposed or susceptible subpopulations that will be considered based on greater exposure.

## 2.4 Hazards

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For scoping, EPA conducted comprehensive searches for data on hazards of perchloroethylene, as described in the supplemental document: *Strategy for Conducting Literature Searches for Perchloroethylene: Supplemental File for the TSCA Scope Document*. Based on initial screening, EPA expects to analyze the hazards of perchloroethylene identified in this problem formulation document. However, when conducting the risk evaluation, the relevance of each hazard within the context of a specific exposure scenario will be judged for appropriateness. For example, hazards that occur only as a result of chronic exposures may not be applicable for acute exposure scenarios. This means that it is unlikely that every hazard identified will be analyzed for every exposure scenario.

### 2.4.1 Environmental Hazards

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EPA identified the following existing sources of environmental hazard data for perchloroethylene: European Chemicals Bureau (ECB) EU Risk Assessment Report Tetrachloroethylene, Part 1 - environment (ECB, 2005a) and World Health Organization (WHO) Concise International Chemical Assessment Document 68; Tetrachloroethylene WHO (WHO, 2006). Only the *on-topic* references listed in the Ecological Hazard Literature Search Results were considered as potentially relevant

data/information sources for the risk evaluation. Inclusion criteria were used to screen the results of the ECOTOX literature search (as explained in the *Strategy for Conducting Literature Searches for Perchloroethylene: Supplemental Document to the TSCA Scope Document, CASRN:127-18-4*. Data from the screened literature are summarized below (Table 2-9) as ranges (min-max). EPA expects to review these data/information sources during risk evaluation using the data quality review evaluation metrics and the rating criteria described in the *Application of Systematic Review in TSCA Risk Evaluations* (U.S. EPA, 2018a).

### ***Toxicity to Aquatic Organisms***

The acute 96-hour LC50 values for fish range from 4 mg/L for Flagfish (*Jordanella floridae*) to 28.1 mg/L for Indian Silverside (*Menidia berylina*). With aquatic invertebrates, the LC/EC50 values ranged from 2.85 – 30.8 mg/L. For algal toxicity 72/96-hr EC50 values were 3.64 – 500 mg/L based on biomass and abundance (Table 2-9).

Chronic aquatic toxicity data for perchloroethylene are available. Chronic toxicity to fish values range from 0.5- 1.4 mg/L. A 28-day Daphnia magna study reported NOEC value of 0.505 mg/L based on reproduction using measured concentrations. Another 28-day Opossum Shrimp (*Americanmysis bahia*) study reported NOEC value of 0.370 mg/L. For the most conservative chronic toxicity values were reported as algal 72-h NOEC= 0.01 – 0.02 mg/L and LOEC= 0.02– 0.05 mg/L. Based on these NOEC and LOEC, the chronic toxicity values are calculated as 0. 0.014 – 0.032 mg/L (Table 2-9).

### ***Toxicity to Soil/Sediment and Terrestrial Organisms***

An earthworm (*Eisenia foetida*) toxicity study of perchloroethylene has been tested using OECD Guideline No. 207. The 14-day LC50 was 100–320 mg/kg, the 28-day NOEC (based upon cocoons) was ≤18 mg/kg, and the 28-day NOEC (based upon appearance) was 18–32 mg/kg. Another perchloroethylene study using the carabid beetle (*Poecilus cupreus*) was conducted. No mortality or behavioral changes were observed in this study (Table 2-9).

For terrestrial plants, a 21-day study of lettuce (*Lactuca sativa*) showed EC50 of 12 mg/L based on biomass. Another study looked at the effects on the early developmental stage of lettuce (*Avena sativa*), germinated plants, the 16-day EC50 (growth) was 861 mg/kg based on the converted standard organic matter content.

**Table 2-9: Ecological Hazard Characterization of Perchloroethylene**

Duration	Test organism	Endpoint	Hazard value*	Units	Effect Endpoint	References
Aquatic Organisms						
Acute	Fish	LC <sub>50</sub>	4 – 28.1	mg/L	Mortality	Smith (1991); Horne (1983)
	Aquatic invertebrates	LC/EC <sub>50</sub>	2.85 – 30.8	mg/L	Immobilization	Hollister (1968); Call (1983) as cited in WHO (2006)
	Algae	EC <sub>50</sub>	3.64 - 500	mg/L	Biomass/ Abundance	Brack (1994) as cited in ECB (2005); U.S. EPA (1980a) as cited in WHO (2006)
	Amphibians	EC <sub>50</sub>	2.5 -20.0	mg/L	Mortality	McDaniel (2004)
	Acute COC	0.80 mg/L				
Chronic	Fish	ChV	0.5-1.4	mg/L	Growth	Ahmad (1984); Smith (1991) as cited in ECB (2005)
	Aquatic invertebrates	ChV	0.37 – 1.11 (NOEC)	mg/L	Mortality/ Reproduction	Hollister (1968); Richter et al. (1983) as cited in ECB (2005); Call (1983) as cited in WHO (2006)
	Algae	NOEC LOEC ChV	0.01-0.02 0.02-0.05 0.014-0.032	mg/L	Abundance	Labra (2010);
	Chronic COC	0.001 mg/L				
Terrestrial Organisms						
Acute	Terrestrial invertebrates	LC <sub>50</sub>	100 - 320	mg/Kg	Cocoons appearance	(Vonk et al., 1986) as cited in WHO (2006)
	Terrestrial plants	EC <sub>50</sub>	861	mg/Kg	Growth	(Bauer and Dietze, 1992) as cited in WHO (2006)
Chronic	Terrestrial plants	EC <sub>50</sub>	12	mg/L	Biomass	Hulzebos, 1993

\* Values in the tables are presented as reported by the study authors

### ***Concentrations of Concern***

The screening-level acute and chronic concentrations of concern (COCs) for perchloroethylene were derived based on the lowest or most toxic ecological toxicity values (e.g., L/EC<sub>50</sub>). The information below describes how the acute and chronic COC's were calculated for environmental toxicity of perchloroethylene using assessment factors.

The application of assessment factors is based on established EPA/OPPT methods (U.S. EPA, 2013, 2012c) and were used in this hazard assessment to calculate lower bound effect levels (referred to as the concentration of concern; COC) that would likely encompass more sensitive species not specifically

represented by the available experimental data. Also, assessment factors are included in the COC calculation to account for differences in inter- and intra-species variability, as well as laboratory-to-field variability. It should be noted that these assessment factors are dependent upon the availability of datasets that can be used to characterize relative sensitivities across multiple species within a given taxa or species group, but are often standardized in risk assessments conducted under TSCA, due to limited data availability.

The concentrations of concern for each endpoint were derived based on the ecological hazard data for perchloroethylene. The information below describes how the acute and chronic COCs were calculated for aquatic toxicity.

The acute COC is derived by dividing acute aquatic invertebrates LC50 of 2.85 mg/L (the lowest acute value in the dataset) by an assessment factor (AF) of 5:

- Lowest value for aquatic invertebrates LC50 (2.85 mg/L) / AF of 5 = 0.57 mg/L or 570 µg/L.

The acute COC of 570 µg/L, derived from experimental aquatic invertebrate's endpoint, is used as a conservative hazard level in this problem formulation for perchloroethylene.

The chronic COC was determined based on the lowest chronic toxicity value divided by an assessment factor of 10.

- Lowest chronic value for 72-h algal ChV = 0.014 mg/L / 10 = 0.0014 mg/L or 1.4 µg/L.

The chronic COC of 1.4 µg/L, derived from experimental algae endpoint, is used as the lower bound hazard level in this problem formulation for perchloroethylene.

## **2.4.2 Human Health Hazards**

Perchloroethylene has an existing EPA IRIS Assessment [U.S. EPA \(2012e\)](#) and a draft ATSDR Toxicological Profile ([ATSDR, 2014](#)); hence, many of the hazards of perchloroethylene have been previously compiled. EPA expects to use these previous analyses as a starting point for identifying key and supporting studies to inform the human health hazard assessment, including dose-response analysis. The relevant studies will be evaluated using the data quality criteria in the *Application of Systematic Review in TSCA Risk Evaluations* document. EPA also expects to consider other studies (e.g., more recently published, alternative test data) that have been published since these reviews, as identified in the literature search conducted by the Agency for perchloroethylene (*Perchloroethylene (CASRN 127-18-4) Bibliography: Supplemental File for the TSCA Scope Document*). EPA expects to consider potential human health hazards associated with perchloroethylene. Based on reasonably available information, the following sections describe the potential hazards associated with perchloroethylene.

### **2.4.2.1 Non-Cancer Hazards**

The EPA IRIS Assessment on perchloroethylene ([U.S. EPA, 2012e](#)) evaluated the following non-cancer hazards that may be associated with perchloroethylene exposures: the central nervous system (neurotoxicity), kidney, liver and development and reproduction. In general, neurological effects were found to be associated with lower perchloroethylene inhalation exposures. According to the EPA IRIS Assessment ([U.S. EPA, 2012e](#)), support for an association with immune and blood effects were less well characterized. In their draft Toxicological Profile for perchloroethylene, [ATSDR \(2014\)](#) identified similar hazard concerns. The National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances ([NAC/AEGL, 2009](#)) also identified irritation as a hazard concern.

### ***Acute Toxicity***

Data from acute exposure studies in animals and human incidents indicate that short term exposure to perchloroethylene may cause irritation and neurotoxicity and can impair cognitive function in humans (U.S. EPA, 2012e). An Acute Exposure Guidance Limit (AEGL) values, established by the National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances (NAC/AEGL, 2009), has been developed based on irritation to humans (AEGL-1), ataxia in rodents (AEGL-2), and lethality in mice (AEGL-3) (NAC/AEGL, 2009).

### ***Neurotoxicity***

Evidence in humans and animals show that chronic exposure to perchloroethylene can cause neurotoxicity, resulting in decrements in color vision, visuospatial memory and possibly other aspects of cognition and neuropsychological function (U.S. EPA, 2012e). Neurotoxic effects have been characterized in human controlled exposure, occupational exposure and residential studies, as well as in experimental animal studies, providing evidence of an association between perchloroethylene exposure and neurological deficits (U.S. EPA, 2012e). The EPA IRIS assessment for perchloroethylene (U.S. EPA, 2012e) further notes that the nervous system is an expected target with oral perchloroethylene exposures because perchloroethylene and metabolites produced from inhalation exposures will also reach the target tissue via oral exposure.

### ***Kidney Toxicity***

Evidence for kidney toxicity in humans is based on studies of kidney biomarkers, which provide information on nephron integrity and tubule damage. Epidemiologic studies support an association between perchloroethylene and chronic kidney disease (U.S. EPA, 2012e). Animal evidence supports an association between perchloroethylene exposure and chronic kidney disease. Adverse effects on the kidney (e.g., kidney-to-body weight ratios, hyaline droplet formation, glomerular “nephrosis,” karyomegaly (enlarged nuclei), cast formation, and other lesions or indicators of renal toxicity) have been observed in studies of rodents exposed to high concentrations of perchloroethylene by inhalation, oral and intraperitoneal (i.p.) injection of perchloroethylene metabolites (U.S. EPA, 2012e).

### ***Liver Toxicity***

Liver toxicity (i.e., necrosis, vacuolation, etc) has been reported in multiple animal species by inhalation and oral exposures to perchloroethylene, with the mouse typically being more sensitive than the rat (U.S. EPA, 2012e). The liver effects are characterized by increased liver weight, necrosis, inflammatory cell infiltration, triglyceride increases proliferation, cytoplasmic vacuolation (fatty changes), pigment in cells, oval cell hyperplasia and regenerative cellular foci. The EPA IRIS Assessment for perchloroethylene (U.S. EPA, 2012e) found suggestive evidence that perchloroethylene is a liver toxicant in humans.

### ***Reproductive/Developmental Toxicity***

The EPA IRIS Assessment for perchloroethylene (U.S. EPA, 2012e) evaluated the developmental and reproductive toxicity of perchloroethylene in humans and animals. Studies of tetrachloroethylene exposure in humans have evaluated several reproductive outcomes including effects on menstrual disorders, semen quality, fertility, time to pregnancy, and risk of adverse pregnancy outcomes including spontaneous abortion, low birth weight or gestational age, birth anomalies, and stillbirth (U.S. EPA, 2012e). Data from animal studies identified various manifestations of developmental toxicity including, increased mortality and decreased body weight in the offspring of rodents exposed via inhalation.

## ***Irritation***

U.S. EPA (2012e) and ATSDR (2014) indicate perchloroethylene is irritating. Irritation data for perchloroethylene have also been reviewed outside the EPA IRIS Assessment. Controlled exposures in humans and case reports have identified eye and nose irritation (NAC/AEGL, 2009).

### **2.4.2.2 Genotoxicity and Cancer Hazards**

Epidemiologic data provide evidence associating perchloroethylene with several cancer types, including non-Hodgkin lymphoma, multiple myeloma and bladder cancer, with more limited evidence for esophageal, kidney, lung, cervical and breast cancer (U.S. EPA, 2012e). Perchloroethylene is generally considered to be non-genotoxic, however several metabolites exhibit mutagenic and/or genotoxic properties and may contribute to potential genotoxic mode of action (MOA) (U.S. EPA, 2012e). In 2012, EPA released the outcome of the weight-of-evidence cancer assessment, which described the weight-of-evidence judgment of the likelihood that perchloroethylene is a human carcinogen, and quantitative estimates of risk from oral and inhalation exposure (U.S. EPA, 2012e). Following U.S. EPA (2005a) Guidelines for Carcinogen Risk Assessment, EPA concluded that perchloroethylene is “likely to be carcinogenic in humans by all routes of exposure” (U.S. EPA, 2012e).

### **2.4.2.3 Potentially Exposed or Susceptible Subpopulations**

TSCA requires that the determination of whether a chemical substance presents an unreasonable risk include consideration of unreasonable risk to “a potentially exposed or susceptible subpopulation identified as relevant to the risk evaluation” by EPA. TSCA § 3(12) states that “the term ‘potentially exposed or susceptible subpopulation’ means a group of individuals within the general population identified by the Administrator who, due to either greater susceptibility or greater exposure, may be at greater risk than the general population of adverse health effects from exposure to a chemical substance or mixture, such as infants, children, pregnant women, workers, or the elderly.”

In developing the hazard assessment, EPA will analyze available data to ascertain whether some human receptor groups may show greater susceptibility to the chemical’s hazards due to intrinsic factors. EPA plans to analyze the susceptibility factors identified in the EPA IRIS assessment for perchloroethylene U.S. EPA (2012e) and ATSDR (2014) evaluations. These assessments both identified the following subpopulations as possibly more susceptible to adverse effects associated with perchloroethylene exposures: early and later lifestages and groups defined by health and nutrition status, gender, race/ethnicity, genetics and multiple exposures and cumulative risk. However U.S. EPA (2012e) also determined that the available data was insufficient to allow for a quantitative assessment of the impact of susceptibility on risk.

The California Office of Environmental Health Hazard Assessment OEHHA (2016) derived an inhalation cancer unit risk factor for perchloroethylene based on the same physiologically based pharmacokinetic (PBPK) model (Chiu and Ginsberg, 2011) used in the EPA IRIS assessment (U.S. EPA, 2012e). The model included both oxidative metabolism and glutathione conjugation metabolism; the latter varies greatly within the human population, with some variation representing sensitive subpopulations (Spearow et al., 2017; OEHHA, 2016). EPA will consider this information during the risk evaluation phase.

## **2.5 Conceptual Models**

EPA risk assessment guidance (U.S. EPA, 2014d), defines Problem Formulation as the part of the risk assessment framework that identifies the major factors to be considered in the assessment. It draws from the regulatory, decision-making and policy context of the assessment and informs the assessment’s technical approach.

A conceptual model describes the actual or predicted relationships between the chemical substance and receptors, either human or environmental. These conceptual models are integrated depictions of the conditions of use, exposures (pathways and routes), hazards and receptors. The initial conceptual models describing the scope of the assessment for perchloroethylene, have been refined during problem formulation. The changes to the conceptual models in this problem formulation are described along with the rationales.

In this section EPA outlines those pathways that will be included and further analyzed in the TSCA risk evaluation; will be included but will not be further analyzed in risk evaluation; and will not be included in the TSCA risk evaluation and the underlying rationale for these decisions.

EPA determined as part of problem formulation that it is not necessary to conduct further analysis on certain exposure pathways that were identified in the perchloroethylene scope document and that remain in the risk evaluation. Each risk evaluation will be "fit-for-purpose," meaning not all conditions of use will warrant the same level of evaluation and the Agency may be able to reach some conclusions without extensive or quantitative risk evaluations. 82 FR 33726, 33734, 33739 (July 20, 2017).

As part of this problem formulation, EPA also identified exposure pathways under regulatory programs of other environmental statutes, administered by EPA, which adequately assess and effectively manage exposures and for which long-standing regulatory and analytical processes already exist, i.e., the Clean Air Act (CAA), the Safe Drinking Water Act (SDWA), the Clean Water Act (CWA) and the Resource Conservation and Recovery Act (RCRA). OPPT worked closely with the offices within EPA that administer and implement the regulatory programs under these statutes. In some cases, EPA has determined that chemicals present in various media pathways (i.e., air, water, land) fall under the jurisdiction of existing regulatory programs and associated analytical processes carried out under other EPA-administered statutes and have been assessed and effectively managed under those programs. EPA believes that the TSCA risk evaluation should generally focus on those exposure pathways associated with TSCA conditions of use that are not adequately assessed and effectively managed under the regulatory regimes discussed above because these pathways are likely to represent the greatest areas of risk concern. As a result, EPA does not expect to include in the risk evaluation certain exposure pathways identified in the perchloroethylene scope document.

### **2.5.1 Conceptual Model for Industrial and Commercial Activities and Uses: Potential Exposures and Hazards**

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The revised conceptual model (Figure 2-2) describes the pathways of exposure from industrial and commercial activities and uses of perchloroethylene that EPA expects to include in the risk evaluation. There are exposures to workers and/or occupational non-users via inhalation routes and/or exposures to workers via dermal routes for all conditions of use identified in this problem formulation. In addition to the pathways illustrated in the figure, EPA will evaluate activities resulting in exposures associated with distribution in commerce (e.g. loading, unloading) throughout the various lifecycle stages and conditions of use (e.g. manufacturing, processing, industrial use, commercial use, disposal) rather than a single distribution scenario.

#### ***Inhalation***

Inhalation exposures for workers are regulated by OSHA's occupational safety and health standards for perchloroethylene which include a PEL of 100 ppm TWA, exposure monitoring, control measures and respiratory protection (29 CFR 1910.134). EPA expects that for workers and occupational non-users exposure via inhalation will be the most significant route of exposure for most exposure scenarios. EPA

expects to further analyze inhalation exposures to vapors and mists for workers and occupational non-users in the risk evaluation.

### ***Dermal***

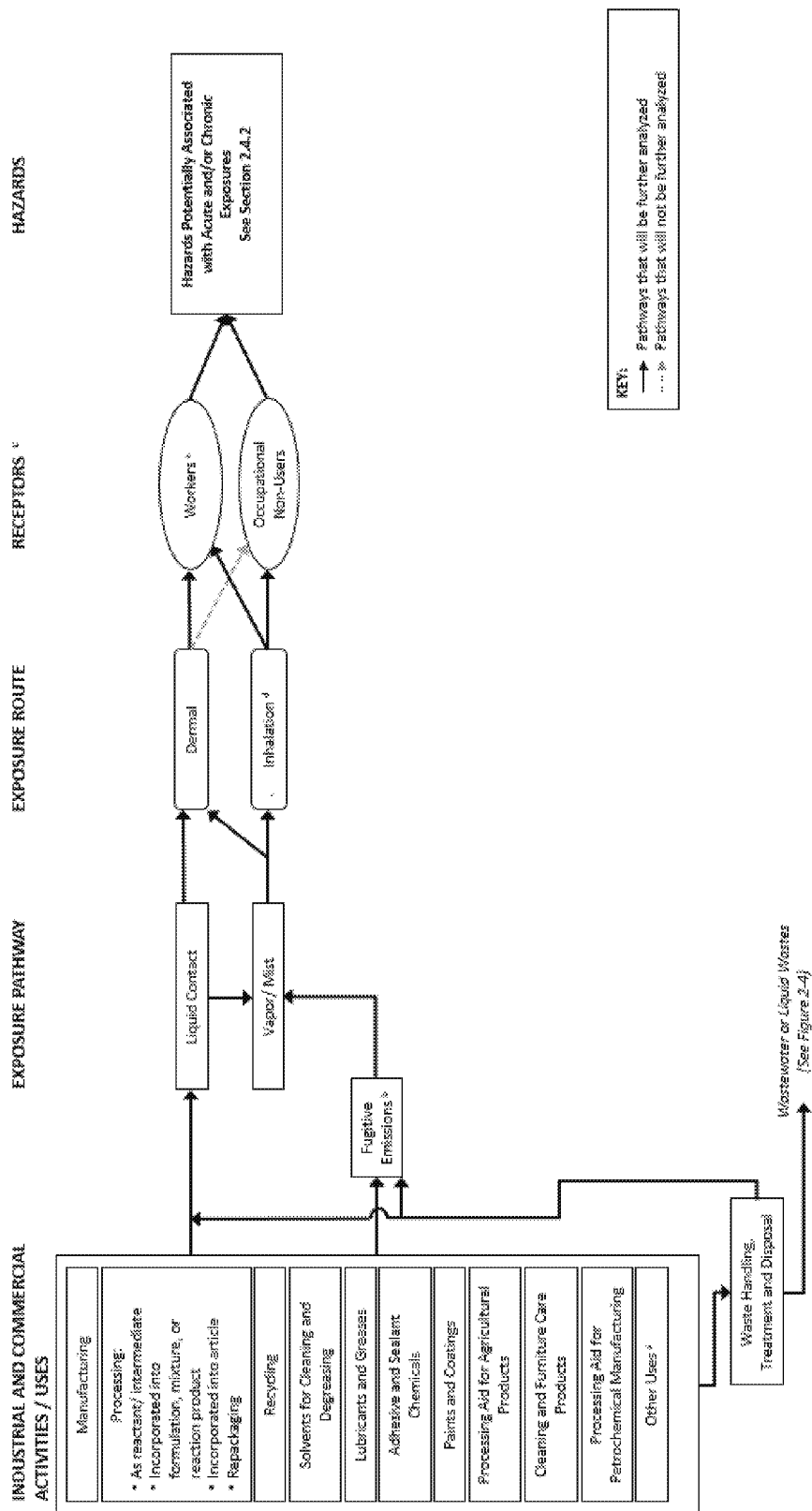
There is the potential for dermal exposures to perchloroethylene in many worker scenarios. Where workers may be exposed to perchloroethylene, the OSHA standard requires that workers are protected from contact (e.g. gloves) (29 CFR 1910.132). Dermal exposures would be concurrent with inhalation exposures and the overall contribution of dermal exposure to the total exposure is expected to be small however there may be exceptions for occluded scenarios. Occupational non-users are not directly handling perchloroethylene; therefore, skin contact with liquid perchloroethylene is not expected for occupational non-users and EPA does not expect to further analyze this pathway in the risk evaluation. EPA expects to further analyze dermal exposures for skin contact with liquids.

The parameters determining the absorption of perchloroethylene vapor are based on the concentration of the vapor, the duration of exposure and absorption. As described by ATSDR, a human study comparing absorption of perchloroethylene vapor via the dermal and inhalation routes (*i.e.*, exposure to vapor with and without respiratory protection) found that absorption via the dermal route is only 1% of the combined dermal and inhalation routes ([ATSDR, 2014](#)). Therefore, EPA will not further analyze worker or occupational non-user exposure via vapor-to-dermal contact, because the contribution to overall exposure will be orders of magnitude lower than direct inhalation of vapors.

### ***Waste Handling, Treatment and Disposal***

Figure 2-2 shows that waste handling, treatment and disposal is expected to lead to the same pathways as other industrial and commercial activities and uses. The path leading from the “Waste Handling, Treatment and Disposal” box to the “Hazards Potentially Associated with Acute and/or Chronic Exposures See Section 2.4.2” box was re-routed to accurately reflect the expected exposure pathways, routes, and receptors associated with these conditions of use of perchloroethylene.

For each condition of use identified in Table 2-3, a determination was made as to whether or not each unique combination of exposure pathway, route, and receptor will be further analyzed in the risk evaluation. The results of that analysis along with the supporting rationale are presented in Appendix C and Appendix E.



**Figure 2-2. Perchloroethylene Conceptual Model for Industrial and Commercial Activities and Uses: Potential Exposures and Hazards**

The conceptual model presents the exposure pathways, exposure routes and hazards to human receptors from industrial and commercial activities and uses of perchloroethylene.

<sup>a</sup> Some products are used in both commercial and consumer applications such as adhesives and sealants. Additional uses of perchloroethylene are included in Table 2-3.

<sup>b</sup> Fugitive air emissions are those that are not stack emissions and include fugitive equipment leaks from valves, pump seals, flanges, compressors, sampling connections and open-ended lines; evaporative losses from surface impoundment and spills; and releases from building ventilation systems.

<sup>c</sup> Receptors include potentially exposed or susceptible subpopulations.

<sup>d</sup> Exposure may occur through mists that deposit in the upper respiratory tract however, based on physical chemical properties, mists of perchloroethylene will likely be rapidly absorbed in the respiratory tract or evaporate and will be considered as an inhalation exposure.

<sup>e</sup> When data and information are available to support the analysis, EPA also considers the effect that engineering controls and/or personal protective equipment have on occupational exposure levels.

### 2.5.2 Conceptual Model for Consumer Activities and Uses: Potential Exposures and Hazards

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The revised conceptual model (Figure 2-3) illustrates the pathways of exposure from consumer uses of perchloroethylene that EPA expects to include in the risk evaluation. It should be noted that some consumers may purchase and use products primarily intended for commercial use.

#### *Inhalation*

EPA expects inhalation to be the primary route of exposure and plans to further analyze inhalation exposures to perchloroethylene vapor and mist for consumers and bystanders.

#### *Dermal*

There is potential for dermal exposures to perchloroethylene from consumer uses. Dermal exposure may occur via direct liquid contact during use. Direct contact with liquid perchloroethylene would be concurrent with inhalation exposures and dermal exposures to consumers in occluded and non-occluded scenarios are expected. Bystanders will not have direct dermal contact with liquid perchloroethylene. EPA expects to further analyze direct dermal contact with liquid perchloroethylene for consumers.

Consumers and bystanders can have skin contact with perchloroethylene vapor concurrently with inhalation exposures. Similar to workers (see Section 2.5.1) the parameters determining the absorption of perchloroethylene vapor are based on the concentration of the vapor, the duration of exposure and absorption. The concentration of the vapor and the duration of exposure are the same for concurrent dermal and inhalation exposures. Therefore, the differences between dermal and inhalation exposures depend on the absorption. As described by ATSDR, a human study comparing absorption of perchloroethylene vapor via the dermal and inhalation routes (*i.e.*, exposure to vapor with and without respiratory protection) found that absorption via the dermal route is only 1% of the combined dermal and inhalation routes ([ATSDR, 2014](#)). Therefore, EPA will not further analyze consumer or bystander exposure via vapor-to-dermal contact, because the contribution to overall exposure will be orders of magnitude lower than direct inhalation of vapors.

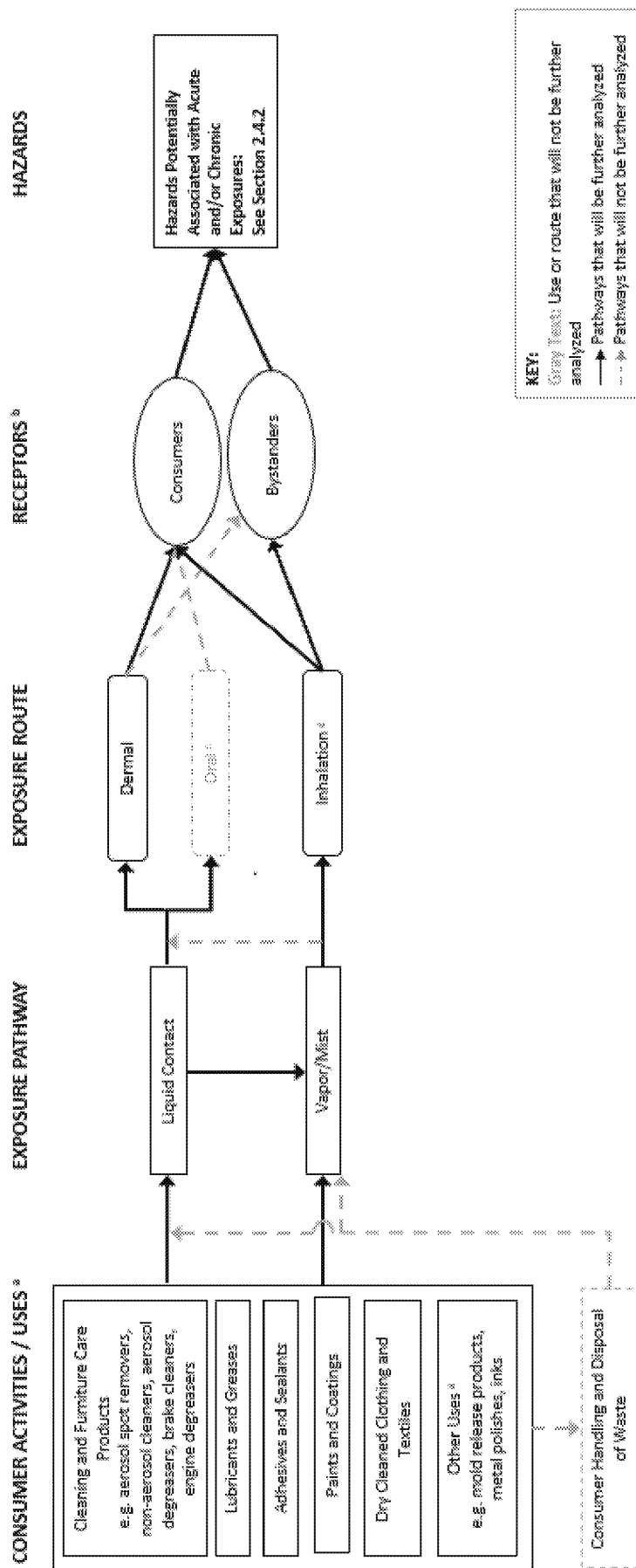
#### *Oral*

Consumers may be exposed to perchloroethylene via transfer of chemical from hand to mouth. This exposure pathway will be limited by a combination of dermal absorption and volatilization; therefore, this pathway will not be further evaluated.

Furthermore, based on available toxicological data, EPA does not expect that considering separate oral routes of exposure for mists or for incidental ingestion would have significantly different toxicity, rather mists will be included as part of consumer inhalation exposures and skin contact will be included as part of consumer dermal exposures. Bystanders are not directly handling perchloroethylene; therefore, inhalation exposure to mists and incidental ingestion via contact with perchloroethylene are not expected for bystanders. EPA plans no further analysis of this pathway for consumers or bystanders.

#### *Disposal*

EPA does not expect to further analyze exposure to consumers from disposal of consumer products. It is anticipated that most products will be disposed of in original containers, particularly those products that are purchased as aerosol cans.



**Figure 2-3. Perchloroethylene Conceptual Model for Consumer Activities and Uses: Potential Exposures and Hazards**

The conceptual model presents the exposure pathways, exposure routes and hazards to human receptors from consumer activities and uses of perchloroethylene.

<sup>a</sup> Some products are used in both commercial and consumer applications. Additional uses of perchloroethylene are included in Table 2.3.

<sup>b</sup> Receptors include potentially exposed or susceptible subpopulations

<sup>c</sup> Consumers may be exposed to perchloroethylene via transfer of chemical from hand to mouth. This exposure pathway will be limited by a combination of dermal absorption and volatilization; therefore, this pathway will not be further evaluated.

### **2.5.3 Conceptual Model for Environmental Releases and Wastes: Potential Exposures and Hazards**

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The revised conceptual model (Figure 2-4) illustrates the expected exposure pathways to human (i.e., general population) and ecological receptors (i.e., aquatic and terrestrial) from environmental releases and waste streams associated with industrial and commercial activities for perchloroethylene that EPA expects to include in the risk evaluation. The pathways that EPA expects to include and analyze further in the risk evaluation is described in Section 2.5.3.1 and shown in the conceptual model Figure 2-4. The pathways that EPA does not expect to include in the risk evaluation s are described in Section 2.5.3.2.

#### **2.5.3.1 Pathways That EPA Expects to Include and Further Analyze in the Risk Evaluation**

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EPA plans to analyze aquatic organisms exposed via contaminated surface water.

There are no national recommended water quality criteria for the protection of aquatic life for perchloroethylene and as a result EPA does not believe that perchloroethylene exposure to aquatic organisms in surface water has been adequately assessed or effectively managed under other EPA statutory authorities (see Section 2.5.3.2). EPA identified and reviewed national scale monitoring data to support this problem formulation. EPA and the USGS National Water Quality Assessment Program (Cycle 1, 1992-2001) reported perchloroethylene contamination in U.S. surface water and ground water in 19.6% of samples (n=5,911) and at 13.2% of sites (n=4,295), with detection in surface water occurring more frequently than in ground water (U.S. EPA, 2009). More recently measured, national-scale monitoring data was from EPA's STORage and RETreival (STORET) and National Water Information System (NWIS). Based on STORET query for perchloroethylene for the past ten years, perchloroethylene is detected in surface water in the United States. The data showed a detection rate (above quantification limit and/or above reporting limit) of approximately 15% for surface water, with detections ranging from 0.02 µg/L to 26.7 µg/L. As summarized in Section 2.4.1 perchloroethylene showed hazard at concentrations as low as 14 µg/L for aquatic plants. The chronic COC value of 1 µg/L is not sufficiently below the range of monitored concentrations to eliminate risk concerns. Therefore, EPA plans to evaluate risks to aquatic organisms from exposures to perchloroethylene in surface waters.

#### **2.5.3.2 Pathways That EPA Does Not Expect to Include in the Risk Evaluation**

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Exposures to receptors may occur from industrial and/or commercial uses, industrial releases to air, water or land; and other conditions of use. As described in section 2.5, pathways under other environmental statutes, administered by EPA, which adequately assess and effectively manage exposures and for which long-standing regulatory and analytical processes already exist will not be included in the risk evaluation. These pathways are described below.

##### **Ambient Air Pathway**

The Clean Air Act (CAA) contains a list of hazardous air pollutants (HAP) and provides EPA with the authority to add to that list pollutants that present, or may present, a threat of adverse human health effects or adverse environmental effects. For stationary source categories emitting HAP, the CAA requires issuance of technology-based standards and, if necessary, additions or revisions to address developments in practices, processes, and control technologies, and to ensure the standards adequately protect public health and the environment. The CAA thereby provides EPA with comprehensive authority to regulate emissions to ambient air of any hazardous air pollutant.

Perchloroethylene is a HAP. EPA has issued a number of technology-based standards for source categories that emit perchloroethylene to ambient air and, as appropriate, has reviewed, or is in the process of reviewing remaining risks. Because stationary source releases of perchloroethylene to ambient air are adequately assessed and any risks effectively managed when under the jurisdiction of the CAA, EPA does not plan to evaluate emission pathways to ambient air from commercial and industrial stationary sources or associated inhalation exposure of the general population or terrestrial species in this TSCA evaluation.

### **Drinking Water Pathway**

EPA has regular analytical processes to identify and evaluate drinking water contaminants of potential regulatory concern for public water systems under the Safe Drinking Water Act (SDWA). Under SDWA, EPA must also review and revise “as appropriate” existing drinking water regulations every 6 years.

EPA has promulgated National Primary Drinking Water Regulations (NPDWRs) for perchloroethylene under the Safe Drinking Water Act. EPA has set an enforceable Maximum Contaminant Level (MCL) as close as feasible to a health based, non-enforceable Maximum Contaminant Level Goal (MCLG). Feasibility refers to both the ability to treat water to meet the MCL and the ability to monitor water quality at the MCL, SDWA Section 1412(b)(4)(D), and public water systems are required to monitor for the regulated chemical based on a standardized monitoring schedule to ensure compliance with the (MCL).

Hence, because the drinking water exposure pathway for perchloroethylene is currently addressed in the SDWA regulatory analytical process for public water systems, EPA does not plan to include this pathway in the risk evaluation for perchloroethylene under TSCA. EPA’s Office of Water and Office of Pollution Prevention and Toxics will continue to work together providing understanding and analysis of the SDWA regulatory analytical processes and to exchange information related to toxicity and occurrence data on chemicals undergoing risk evaluation under TSCA.

### **Ambient Water Pathways**

EPA develops recommended water quality criteria under section 304(a) of the CWA for pollutants in surface water that are protective of aquatic life or human health designated uses. EPA develops and publishes water quality criteria based on priorities of states and others that reflect the latest scientific knowledge. A subset of these chemicals are identified as “priority pollutants” (103 human health and 27 aquatic life). The CWA requires states adopt numeric criteria for priority pollutants for which EPA has published recommended criteria under section 304(a), the discharge or presence of which in the affected waters could reasonably be expected to interfere with designated uses adopted the state. When states adopt criteria that EPA approves as part of state’s regulatory water quality standards, exposure is considered when state permit writers determine if permit limits are needed and at what level for a specific discharger of a pollutant to ensure protection of the designated uses of the receiving water. Once states adopt criteria as water quality standards, the CWA requires National Pollutant Discharge Elimination System (NPDES) discharge permits include effluent limits as stringent as necessary to meet standards. CWA section 301(b)(1)(C). This is the process used under the CWA to address risk to human health and aquatic life from exposure to a pollutant in ambient waters.

EPA has identified perchloroethylene as a priority pollutant and EPA has developed recommended water quality criteria for protection of human health for perchloroethylene which are available for adoption into state water quality standards for the protection of human health and are available for use by NPDES permitting authorities in deriving effluent limits to meet state narrative criteria. As such,

EPA does not expect to include this pathway in the risk evaluation under TSCA. EPA's Office of Water and Office of Pollution Prevention and Toxics will continue to work together providing understanding and analysis of the CWA water quality criteria development process and to exchange information related to toxicity of chemicals undergoing risk evaluation under TSCA. EPA may update its CWA section 304(a) water quality criteria for perchloroethylene in the future under the CWA.

EPA has not developed CWA section 304(a) recommended water quality criteria for the protection of aquatic life for perchloroethylene, so there are no national recommended criteria for this use available for adoption into state water quality standards and available for use in NPDES permits. As a result, this pathway will undergo aquatic life risk evaluation under TSCA (see Section 2.4.1). EPA may publish CWA section 304(a) aquatic life criteria for perchloroethylene in the future if it is identified as a priority under the CWA.

### **Biosolids Pathways**

CWA Section 405(d) requires EPA to 1) promulgate regulations that establish numeric criteria and management practices that are adequate to protect public health and the environment from any reasonably anticipated adverse effects of toxic pollutants during the use or disposal of sewage sludge, and 2) review such regulations at least every two years to identify additional toxic pollutants that occur in biosolids (i.e., "Biennial Reviews") and regulate those pollutants if sufficient scientific evidence shows they may be present in sewage sludge in concentrations which may adversely affect public health or the environment. EPA also periodically conducts surveys to determine what may be present in sewage sludge. EPA has conducted four sewage sludge surveys and identified compounds that occur in biosolids in seven Biennial Reviews. EPA has regulated 10 chemicals in biosolids under CWA 405(d).

EPA has identified perchloroethylene in biosolids biennial reviews. The purpose of such reviews is to identify additional toxic pollutants in biosolids. EPA can potentially regulate those pollutants under CWA 405(d), based on a subsequent assessment of risk. EPA's Office of Water is currently developing modeling tools in order to conduct risk assessments for chemicals in biosolids. Because the biosolids pathway for perchloroethylene is currently being addressed in the CWA regulatory analytical process, this pathway will not be further analyzed in the risk evaluation for perchloroethylene under TSCA. EPA's Office of Water and Office of Pollution Prevention and Toxics will continue to work together to discuss significant data gaps and exchange information related to exposure and toxicity of this chemical as OW conducts the risk assessment under the CWA.

### **Disposal Pathways**

Perchloroethylene is included on the list of hazardous wastes pursuant to RCRA 3001 (40 CFR §§ 261.33) as a listed waste on the F, K and U lists. The general RCRA standard in Section RCRA 3004(a) for the technical criteria that govern the management (treatment, storage, and disposal) of hazardous waste are those "necessary to protect human health and the environment," RCRA 3004(a). The regulatory criteria for identifying "characteristic" hazardous wastes and for "listing" a waste as hazardous also relate solely to the potential risks to human health or the environment. 40 C.F.R. §§ 261.11, 261.21-261.24. RCRA statutory criteria for identifying hazardous wastes require EPA to "tak[e] into account toxicity, persistence, and degradability in nature, potential for accumulation in tissue, and other related factors such as flammability, corrosiveness, and other hazardous characteristics." Subtitle C control cover not only hazardous wastes that are landfilled, but also hazardous wastes that are incinerated (subject to joint control under RCRA Subtitle C and the Clean Air Act (CAA) hazardous waste combustion MACT) or injected into UIC Class I hazardous waste wells (subject to joint control under Subtitle C and the Safe Drinking Water Act (SDWA)).

EPA does not expect to include emissions to ambient air from municipal and industrial waste incineration and energy recovery units in the risk evaluation, as they are regulated under section 129 of the Clean Air Act. CAA section 129 also requires EPA to review and, if necessary, add provisions to ensure the standards adequately protect public health and the environment. Thus, combustion by-products from incineration treatment of perchloroethylene wastes (the majority of the 1.1 million lbs identified as treated in Tables 2-6 – 2-8) would be subject to these regulations, as would perchloroethylene burned for energy recovery (2.3 million lbs).

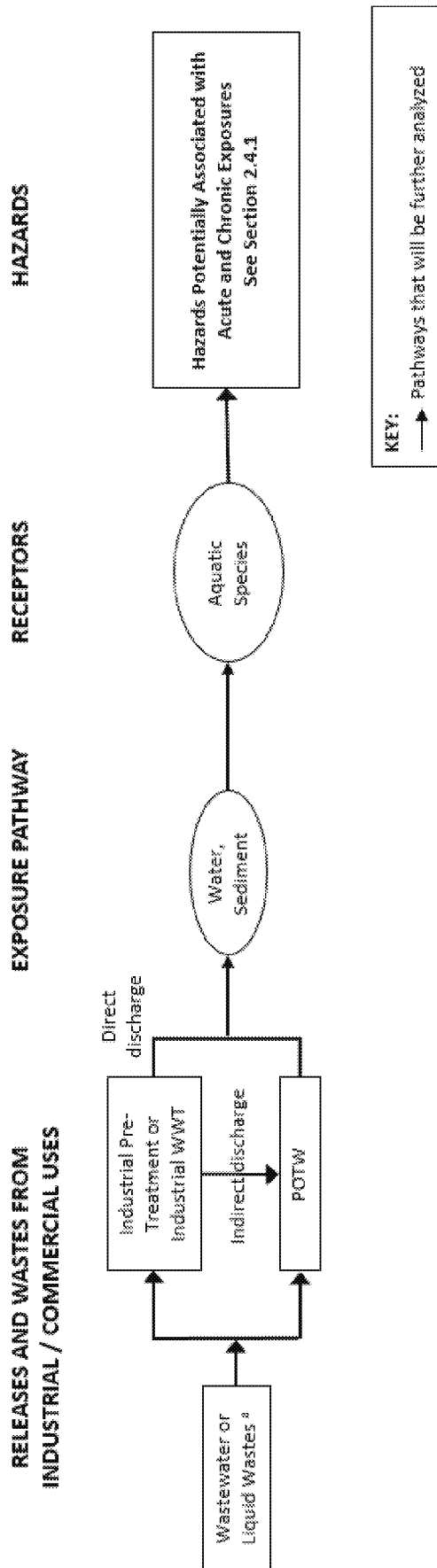
EPA does not expect to include on-site releases to land that go to underground injection in its risk evaluation. TRI reporting in 2016 indicated 272 pounds released to underground injection to a Class I well and no releases to underground injection wells of Classes II-VI. Environmental disposal of perchloroethylene injected into Class I well types managed and prevented from further environmental release by RCRA and SDWA regulations. Therefore, disposal of perchloroethylene via underground injection is not likely to result in environmental and general population exposures.

EPA does not expect to include on-site releases to land from RCRA Subtitle C hazardous waste landfills or exposures of the general population (including susceptible populations) or terrestrial species from such releases in the TSCA evaluation. Based on 2015 reporting to TRI, the majority of the land disposals occur in Subtitle C landfills (78,120 lbs). Design standards for Subtitle C landfills require double liner, double leachate collection and removal systems, leak detection system, run on, runoff, and wind dispersal controls, and a construction quality assurance program. They are also subject to closure and post-closure care requirements including installing and maintaining a final cover, continuing operation of the leachate collection and removal system until leachate is no longer detected, maintaining and monitoring the leak detection and groundwater monitoring system. Bulk liquids may not be disposed in Subtitle C landfills. Subtitle C landfill operators are required to implement an analysis and testing program to ensure adequate knowledge of waste being managed, and to train personnel on routine and emergency operations at the facility. Hazardous waste being disposed in Subtitle C landfills must also meet RCRA waste treatment standards before disposal. Given these controls, general population exposure to perchloroethylene in groundwater from Subtitle C landfill leachate is not expected to be a significant pathway.

EPA does not expect to include on-site releases to land from RCRA Subtitle D municipal solid waste landfills or exposures of the general population (including susceptible populations) or terrestrial species from such releases in the TSCA evaluation. While permitted and managed by the individual states, municipal solid waste (MSW) landfills are required by federal regulations to implement some of the same requirements as Subtitle C landfills. MSW landfills generally must have a liner system with leachate collection and conduct groundwater monitoring and corrective action when releases are detected. MSW landfills are also subject to closure and post-closure care requirements, and must have financial assurance for funding of any needed corrective actions. MSW landfills have also been designed to allow for the small amounts of hazardous waste generated by households and very small quantity waste generators (less than 220 lbs per month). Bulk liquids may not be disposed in Subtitle C landfills.

EPA does not expect to include on-site releases to land from industrial non-hazardous waste and construction/demolition waste landfills in the perchloroethylene risk evaluation. Industrial non-hazardous and construction/demolition waste landfills are primarily regulated under state regulatory programs. States must also implement limited federal regulatory requirements for siting, groundwater monitoring and corrective action and a prohibition on open dumping and disposal of bulk liquids. States

may also establish additional requirements such as for liners, post-closure and financial assurance, but are not required to do so. Therefore, EPA does not expect to include this pathway in the risk evaluation.



**Figure 2-4. Perchloroethylene Conceptual Model for Environmental Releases and Wastes: Potential Exposures and Hazards**

The conceptual model presents the exposure pathways, exposure routes and hazards to human and environmental receptors from environmental releases and wastes of perchloroethylene that will be analyzed.

<sup>a</sup> Industrial wastewater or liquid wastes may be treated on-site and then released to surface water (direct discharge) or pre-treated and released to POTW (indirect discharge).

## 2.6 Analysis Plan

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The analysis plan presented in the problem formulation elaborates on the initial analysis plan that was published in the *Scope of the Risk Evaluation for Perchloroethylene* (U.S. EPA, 2017c).

The analysis plan outlined here is based on the conditions of use for perchloroethylene, as described in Section 2.2 of this problem formulation. EPA is implementing systematic review approaches to identify, select, assess, integrate and summarize the findings of studies supporting the TSCA risk evaluation. The analytical approaches and considerations in the analysis plan are used to frame the scope of the systematic review activities for this assessment. The supplemental document, *Application of Systematic Review in TSCA Risk Evaluations*, provides additional information about criteria and methods that have been and will be applied to the first 10 chemical risk evaluations.

While EPA has conducted a comprehensive search for reasonably available data, as described in the *Scope of the Risk Evaluation for Perchloroethylene* (U.S. EPA, 2017c), EPA encourages submission of additional existing data, such as full study reports or workplace monitoring from industry sources, that may be relevant for refining conditions of use, exposures, hazards and potentially exposed or susceptible subpopulations during risk evaluation. EPA will continue to consider new information submitted by the public.

During risk evaluation, EPA will rely on the comprehensive literature results [*Perchloroethylene* (CASRN 127-18-4) *Bibliography: Supplemental File for the TSCA Scope Document* (EPA-HQ-OPPT-2016-0732)] or supplemental literature searches to address specific questions. Further, EPA may consider any relevant confidential business information (CBI) in the risk evaluation in a manner that protects the confidentiality of the information from public disclosure. The analysis plan is based on EPA's knowledge of perchloroethylene to date, which includes partial, but not complete review of identified literature. If additional data or approaches become available, EPA may refine its analysis plan based on this information.

### 2.6.1 Exposure

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Based on their physical-chemical properties, expected sources, and transport and transformation within the outdoor and indoor environment chemical substances are more likely to be present in some media and less likely to be present in others. Media-specific levels will vary based on the chemical substance of interest. For most chemical substances level(s) can be characterized through a combination of available monitoring data and modeling approaches.

#### 2.6.1.1 Environmental Releases

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EPA expects to consider and analyze releases to relevant environmental media as follows:

- 1) Review reasonably available published literature or information on processes and activities associated with the conditions of use to evaluate the types of releases and wastes generated. EPA has reviewed some key data sources containing information on processes and activities resulting in releases, and the information found is shown in Appendix B-1. EPA will continue to review potentially relevant data sources identified in Table Apx B-3.1 in Appendix B during risk evaluation.

EPA plans to review the following key data sources in Table 2-10 for additional information on activities resulting in environmental releases. The evaluation strategy for engineering and

occupational data sources discussed in the *Application of Systematic Review in TSCA Risk Evaluations* describes how data, information, and studies will be reviewed.

**Table 2-10. Potential Sources of Environmental Release Data**

U.S. EPA TRI Data (Reporting Year 2016 only)
U.S. EPA Generic Scenarios
OECD Emission Scenario Documents
EU Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) Specific Environmental Release Categories (SpERC) factsheets
Discharge Monitoring Report (DMR) surface water discharge data for perchloroethylene from NPDES-permitted facilities

- 2) Review reasonably available chemical-specific release data, including measured or estimated release data (e.g., data collected under the TRI program). EPA has reviewed key release data sources including the Toxics Release Inventory (TRI), and the data from this source is summarized in Section 2.3.2 above and also in Appendix B. EPA will continue to review relevant data sources as identified in Table Apx B-3.2 in Appendix B during risk evaluation. EPA will match identified data to applicable conditions of use and identify data gaps where no data are found for particular conditions of use. EPA will attempt to address data gaps identified as described in steps 3 and 4 below by considering potential surrogate data and models.
- 3) Review reasonably available measured or estimated release data for surrogate chemicals that have similar uses and chemical and physical properties. Data for solvents that are used in the same types of applications may be considered as surrogate data for perchloroethylene. As with perchloroethylene, trichloroethylene is used in paints and coatings, in adhesives and sealants, and as solvents for cleaning and degreasing. EPA will evaluate the use of data for solvents such as trichloroethylene as surrogates to fill data gaps where uses of perchloroethylene and other solvents align. If surrogate data are used, EPA normally converts air concentrations using the ratio of the vapor pressures of the two chemicals. EPA will review literature sources identified and if surrogate data are found, EPA will match these data to applicable conditions of use for potentially filling data gaps.
- 4) Understand and consider regulatory limits that may inform estimation of environmental releases. EPA has identified information from various EPA statutes (including, for example, regulatory limits, reporting thresholds or disposal requirements) that may be relevant to release estimation. Some of the information has informed revision of the conceptual models during problem formulation. EPA will further consider relevant regulatory requirements in estimating releases during risk evaluation.
- 5) Review and determine applicability of OECD Emission Scenario Documents (ESDs) and EPA Generic Scenarios to estimation of environmental releases. Potentially relevant OECD Emission Scenario Documents (ESDs) and EPA Generic Scenarios (GS) have been identified that correspond to some conditions of use. For example, the ESD on Industrial Use of Adhesives for Substrate Bonding, the ESD on the Coating Industry (Paints, Lacquers and Varnishes), and the GS on the Use of Vapor Degreasers are some of the ESDs and GSs that EPA may use to assess potential releases. EPA will need to critically review these generic scenarios and ESDs to determine their applicability to the conditions of use assessed. EPA was not able to identify ESDs or GSs corresponding to several conditions of use, including use of perchloroethylene as

an intermediate, recycling of perchloroethylene, use of perchloroethylene as an industrial processing aid, and use of perchloroethylene in commercial carpet cleaning. EPA will perform additional targeted research to understand those conditions of use which may inform identification of release scenarios. EPA may also need to perform targeted research for applicable models and associated parameters that EPA may use to estimate releases for certain conditions of use. If ESDs and GSs are not available, other methods may be considered. Additionally, for conditions of use where no measured data on releases are available, EPA may use a variety of methods including the application of default assumptions such as standard loss fractions associated with drum cleaning (3%) or single process vessel cleanout (1%).

- 6) Map or group each condition(s) of use to a release assessment scenario. EPA has identified release scenarios and mapped them to some conditions of use. For example, some scenario groupings include Contractor Adhesive Removal and Industrial In-line Vapor Degreasing. EPA grouped similar conditions of use (based on factors including process equipment and handling, release sources and usage rates of perchloroethylene and formulations containing perchloroethylene, or professional judgment) into scenario groupings but may further refine these groupings as additional information becomes available during risk evaluation. EPA was not able to identify release scenarios corresponding to several conditions of use due to a lack of general knowledge of those conditions of use. EPA will perform additional targeted research to understand those uses which may inform identification of release scenarios.
- 7) Complete the weight of the evidence of environmental release data. EPA will rely on the weight of the scientific evidence when evaluating and integrating environmental release data. The data integration strategy will be designed to be fit-for-purpose in which EPA will use systematic review methods to assemble the relevant data, evaluate the data for quality and relevance, including strengths and limitations, followed by synthesis and integration of the evidence.

#### **2.6.1.2 Environmental Fate**

EPA expects to consider and analyze fate and transport in environmental media as follows:

- 1) Review reasonably available measured or estimated environmental fate endpoint data collected through the literature search.

Key environmental fate characteristics were included in assessments conducted by the EPA Integrated Risk Information System ([U.S. EPA, 2012d](#)), EPA Office of Water ([U.S. EPA, 2015b](#)), US Agency for Toxic Substances and Disease Registry ([ATSDR, 2014](#)) and European Chemicals Bureau ([ECB, 2005b](#)). These information sources will be used as a starting point for the environmental fate assessment. Other sources that will be consulted include those that are identified through the systematic review process. Studies will be evaluated using the evaluation strategies laid out in *Application of Systematic Review in TSCA Risk Evaluations*.

If measured values resulting from sufficiently high-quality studies are not available (to be determined through the systematic review process), chemical properties will be estimated using

EPI Suite, SPARC, and other chemical parameter estimation models. Estimated fate properties will be reviewed for applicability and quality.

- 2) Using measured environmental fate data and/or environmental fate modeling, determine the influence of environmental fate endpoints (e.g., persistence, bioaccumulation, partitioning, transport) on exposure pathways and routes of exposure to environmental receptors.

Measured fate data including volatilization from water, sorption to organic matter in soil and sediments, aqueous and atmospheric photolysis rates, and aerobic and anaerobic biodegradation rates, along with physical-chemical properties and models such as the EPI Suite™ STP model (which estimates removal in wastewater treatment due to adsorption to sludge and volatilization to air) and volatility model (which estimates half-life from volatilization from a model river and model lake), will be used to characterize the movement of perchloroethylene within and among environmental media and the persistence of perchloroethylene in media.

- 3) Evaluate the weight of the evidence of environmental fate data.  
EPA will rely on the weight of the scientific evidence when evaluating and integrating environmental fate data. The data integration strategy will be designed to be fit-for-purpose in which EPA will use systematic review methods to assemble the relevant data, evaluate the data for quality and relevance, including strengths and limitations, followed by synthesis and integration of the evidence.

#### **2.6.1.3 Environmental Exposures**

EPA expects to consider the following in developing its environmental exposure assessment of perchloroethylene:

- 1) Refine and finalize exposure scenarios for environmental receptors by considering unique combinations of sources (use descriptors), exposure pathways, exposure settings, populations exposed, and exposure routes. For perchloroethylene, exposure scenarios for environmental receptors include exposures from surface water.
- 2) Review reasonably available environmental and biological monitoring data for environmental exposure to surface water. EPA will rely on databases (see examples below) and literature obtained during systematic review to include ranges and trends of chemical in surface water, including any trends seen in concentrations and spatial trends.
  - STORET and NWIS (USGS/EPS): <https://www.epa.gov/waterdata/storage-and-retrieval-and-water-quality-exchange#portal>
  - OPPT monitoring database
- 3) Review reasonably available information on releases to determine how modeled estimates of concentrations near industrial point sources compare with available monitoring data. Available exposure models that estimate surface water (e.g. E-FAST) will be evaluated and considered alongside available surface water data to characterize environmental exposures. Modeling approaches to estimate surface water concentrations generally consider the following inputs: direct release into surface water and transport (partitioning within media) and characteristics of the environment (river flow, volume of pond, meteorological data).

- 4) Determine applicability of existing additional contextualizing information for any monitored data or modeled estimates during risk evaluation. For example, site/location, time period, and conditions under which monitored data were collected will be evaluated to determine relevance and applicability to wider scenario development. Any studies which relate levels of perchloroethylene in the environment or biota with specific sources or groups of sources will be evaluated.
- 5) Evaluate the weight of evidence of environmental occurrence data and modeled estimates. EPA will rely on the weight of the scientific evidence when evaluating and integrating environmental exposure data. The data integration strategy will be designed to be fit-for-purpose in which EPA will use systematic review methods to assemble the relevant data, evaluate the data for quality and relevance, including strengths and limitations, followed by synthesis and integration of the evidence. Refer to the supplemental document, Application of Systematic Review in TSCA Risk Evaluations, for more information on the general process for data integration.

#### 2.6.1.4 Occupational Exposures

EPA expects to consider and analyze both worker and occupational non-user exposures as follows:

- 1) Review reasonably available exposure monitoring data for specific condition(s) of use. EPA expects to review exposure data including workplace monitoring data collected by government agencies such as the Occupational Safety and Health Administration (OSHA) and the National Institute of Occupational Safety and Health (NIOSH), and monitoring data found in published literature. These workplace monitoring data include personal exposure monitoring data (direct exposures) and area monitoring data (indirect exposures).

EPA has reviewed available monitoring data collected by OSHA and NIOSH and will match these data to applicable conditions of use. EPA has also identified additional data sources that may contain relevant monitoring data for the various conditions of use. EPA will review these sources (identified in Table 2-11 and in Table Apx-B-3.3) and extract relevant data for consideration and analysis during risk evaluation.

OSHA has established a permissible exposure limit (PEL) of 100 ppm 8-hour time-weighted average (TWA). The American Conference of Government Industrial Hygienists (ACGIH) has established a Threshold Limit Value (TLV) of 25 ppm 8-hour TWA. Also, NIOSH has established an immediately dangerous to life or health (IDLH) value of 150 ppm. EPA will consider the influence of these regulatory limits and recommended exposure guidelines on occupational exposures in the occupational exposure assessment.

Table 2-11. Potential Sources of Occupational Exposure Data

2014 Draft ATSDR Toxicological Profile for Perchloroethylene
U.S. OSHA Chemical Exposure Health Data (CEHD) program data
U.S. NIOSH Health Hazard Evaluation (HHE) Program reports
1985 EPA Occupational Exposure and Release Assessment for Tetrachloroethylene

- 2) Review reasonably available exposure data for surrogate chemicals that have uses, volatility and chemical and physical properties similar to perchloroethylene. EPA will review literature sources identified and if surrogate data are found, these data will be matched to applicable conditions of use for potentially filling data gaps. For several conditions of use (e.g., vapor degreasing, cold cleaning, coating applications, adhesive applications), EPA believes trichloroethylene and other

similar solvents that share the same conditions of use may serve as surrogate for perchloroethylene.

- 3) For conditions of use where data is limited or not available, review existing exposure models that may be applicable in estimating exposure levels. EPA has identified potentially relevant OECD ESDs and EPA GS corresponding to some conditions of use. For example, the ESD on Industrial Use of Adhesives for Substrate Bonding, the ESD on Metalworking Fluids, and the GS for Textile Finishing are some of the ESDs and GS's that EPA may use to estimate occupational exposures. EPA will need to critically review these generic scenarios and ESDs to determine their applicability to the conditions of use assessed. EPA was not able to identify ESDs or GS's corresponding to several conditions of use, including use of perchloroethylene as an intermediate, recycling of perchloroethylene, use as an industrial processing aid, and commercial carpet cleaning. EPA will perform additional targeted research to understand those conditions of use, which may inform identification of exposure scenarios. EPA may also need to perform targeted research to identify applicable models that EPA may use to estimate exposures for certain conditions of use.

EPA was not able to identify release scenarios corresponding to several conditions of use. EPA may conduct industry outreach efforts or perform supplemental, targeted literature searches to better understand the process steps involved in that condition of use before occupational exposure assessment can be made. EPA will perform additional targeted research to understand those conditions of use, which may inform identification of exposure scenarios. EPA will consider exposure models in the Chemical Screening Tool For Exposure and Environmental Releases (ChemSTEER) Tool that are routinely used for assessing new chemicals. EPA may also need to perform targeted research to identify other applicable models that EPA could use to estimate exposures for certain conditions of use.

- 4) Review reasonably available data that may be used in developing, adapting or applying exposure models to the particular risk evaluation. This step will be performed after Steps #2 and #3 above. Based on information developed from Step #2 and Step #3, EPA will evaluate relevant data to determine whether the data can be used to develop, adapt, or apply models for specific conditions of use (and corresponding exposure scenarios). EPA may utilize existing, peer-reviewed exposure models developed by EPA/OPPT, other government agencies, or available in the scientific literature, or EPA may elect to develop additional models to assess specific condition(s) of use. Inhalation exposure models may be simple box models or two-zone (near-field/far-field) models. In two-zone models, the near-field exposure represents potential inhalation exposures to workers, and the far-field exposure represents potential inhalation exposures to occupational non-users.

As part of the 2014 risk assessment (RA) and subsequent Section 6 rulemaking for TCE and the 2016 draft RA for 1-BP, EPA developed models to assess inhalation exposures to workers and occupational non-users during the use of these chemicals in dry cleaning, spot cleaning, vapor degreasing, cold cleaning, and aerosol degreasing. During risk evaluation, EPA will evaluate the applicability of these models to perchloroethylene, and adapt and refine these models as necessary for evaluating exposure to perchloroethylene in these scenarios.

EPA will consider the effect of evaporation when evaluating options for dermal exposure assessment. In addition, EPA will consider the impact of occluded exposure or repeated dermal

contacts. EPA anticipates that existing EPA/OPPT dermal exposure models would not be suitable for quantifying dermal exposure to semi-volatile chemicals such as perchloroethylene.

- 5) Consider and incorporate applicable engineering controls and/or personal protective equipment into exposure scenarios. EPA will review potentially relevant data sources on engineering controls and personal protective equipment as identified in Table\_Apx B-3.4 in the Appendix and to determine their applicability and incorporation into exposure scenarios during risk evaluation. EPA will assess worker exposure pre- and post-implementation of engineering controls, using available information on available control technologies and control effectiveness. For example, EPA may assess worker exposure in industrial use scenarios before and after implementation of local exhaust ventilation.
- 6) Map or group each condition of use to occupational exposure assessment scenario(s). EPA has identified exposure scenarios and mapped them to some (or most) conditions of use. EPA was not able to identify occupational exposure scenarios corresponding to several conditions of use due generally to a lack of understanding of those conditions of use (e.g., use of perchloroethylene metal and stone polishes). EPA will perform targeted research to understand those uses which may inform identification of occupational exposure scenarios. EPA grouped similar conditions of use (based on factors including process equipment and handling, usage rates of perchloroethylene and formulations containing perchloroethylene, exposure/release sources) into scenario groupings but may further refine these groupings as additional information is identified during risk evaluation.
- 7) Evaluate the weight of the evidence of occupational exposure data. EPA will rely on the weight of the scientific evidence when evaluating and integrating occupational data. The data integration strategy will be designed to be fit-for-purpose in which EPA will use systematic review methods to assemble the relevant data, evaluate the data for quality and relevance, including strengths and limitations, followed by synthesis and integration of the evidence. Refer to the *Application of Systematic Review in TSCA Risk Evaluations* document for more information on the general process for data integration.

#### **2.6.1.5 Consumer Exposures**

EPA expects to consider and analyze both consumers using a consumer product and bystanders associated with the consumer using the product as follows:

- 1) Refine and finalize exposure scenarios for consumers by mapping sources of exposure (i.e., consumer products), exposure pathways, exposure settings, exposure routes, and populations exposed. Considerations for constructing exposure scenarios for consumers:
  - Reasonably available data on consumer products or products available for consumer use including the weight fraction of perchloroethylene in products;
  - Information characterizing the use patterns of consumer products containing perchloroethylene including the following: intended or likely consumer activity, method of application (e.g., spray-applied, brush-applied, dip), formulation type, amount of product used, frequency and duration of individual use events, and room or setting of use;
  - The associated route of exposure for consumers; and
  - Populations who may be exposed to products as users or bystanders in the home, including potentially exposed and susceptible subpopulations such as children or women

of child bearing age and subsets of consumers who may use commercially-available products or those who may use products more frequently than typical consumers. During consumer exposure modeling, these factors determine the resulting exposure route and magnitude. For example, while the product with the highest weight fraction in a given consumer product scenario could be run early on to indicate preliminary levels of exposure, that product may not actually result in the highest potential exposure due to having a lower frequency of use.

- 2) Evaluate the potential and magnitude of exposure routes based on available data. perchloroethylene, inhalation of vapor is expected to result in higher exposure to consumers and bystanders in the home compared to dermal absorption through direct contact due to fate and exposure properties. The data sources associated with these respective pathways have not been comprehensively evaluated, therefore quantitative comparisons across exposure pathways or in relation to toxicity thresholds are not yet possible.
- 3) Review and use existing indoor exposure models that may be applicable in estimating inhalation and dermal exposure. For example, the Consumer Exposure Model (CEM version 2.0) and the Multi-Chamber Concentration and Exposure Model (MCCEM) to estimate and evaluate indoor exposures to perchloroethylene in consumer and commercial products.
- 4) Review reasonably available empirical data that may be used in developing, adapting or applying exposure models to the particular risk evaluation. For example, existing models developed for a chemical assessment may be applicable to another chemical assessment if model parameter data are available.
- 5) Review reasonably available consumer product-specific sources to determine how those exposure estimates compare with each other and with indoor air and product use monitoring data for perchloroethylene.
- 6) Review reasonably available population- or subpopulation-specific exposure factors and activity patterns to determine if potentially exposed or susceptible subpopulations need be further refined. Based on hazard concerns, certain subpopulations such as pregnant women may be included for any consumer use scenarios, as a user or bystander. For a small subset of uses (e.g. craft glues and adhesives) children may be users of perchloroethylene containing products. For other uses of perchloroethylene containing products children and/or infants would generally not be considered “users”, but may be assessed as bystanders of consumer uses in the home. Other subpopulations may be subject to greater exposure, such as DIY users or those in the business of arts and crafts. Considerations will include:
  - Age-specific differences (exposure factors and activity patterns) for populations defined in the exposure scenarios. Exposure factors and activities patterns will be sourced from EPA’s 2011 Exposure Factors Handbook.
  - Characteristics of the user of the consumer product and the bystander in the room, including for example, women of child bearing age and children.
  - Subpopulations that may have greater exposure due to magnitude, frequency or duration of exposure.
- 7) Evaluate the weight of evidence of consumer exposure estimates based on different approaches. EPA will rely on the weight of the scientific evidence when evaluating and integrating consumer exposure data. The data integration strategy will be designed to be fit-for-purpose in which EPA

will use systematic review methods to assemble the relevant data, evaluate the data for quality and relevance, including strengths and limitations, followed by synthesis and integration of the evidence. Refer to the supplemental document, *Application of Systematic Review in TSCA Risk Evaluations* for more information on the general process for data evaluation. Map or group each condition of use to consumer exposure assessment scenario(s). Refine and finalize exposure scenarios for consumers by mapping sources of exposure (i.e., consumer products), exposure pathways, exposure settings, exposure routes, and populations exposed. Considerations for constructing exposure scenarios for consumers:

#### **2.6.1.6 General Population**

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EPA does not expect to consider and analyze general population exposures in the risk evaluation for perchloroethylene. EPA has determined that the existing regulatory programs and associated analytical processes have addressed or are in the process of addressing potential risks of perchloroethylene that may be present in various media pathways (e.g., air, water, land) for the general population. For these cases, EPA believes that the TSCA risk evaluation should focus not on those exposure pathways, but rather on exposure pathways associated with TSCA uses that are not subject to those regulatory processes.

### **2.6.2 Hazards (Effects)**

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#### **2.6.2.1 Environmental Hazards**

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EPA will conduct an environmental hazard assessment of perchloroethylene as follows:

- 1) Review reasonably available environmental hazard data, including data from alternative test methods (e.g., computational toxicology and bioinformatics; high-throughput screening methods; data on categories and read-across; in vitro studies).

Environmental hazard data will be evaluated using the ecological toxicity data quality criteria outlined in the *Application of Systematic Review in TSCA Risk Evaluations* document. The study evaluation results will be documented in the risk evaluation phase and data from suitable studies will be extracted and integrated in the risk evaluation process.

Conduct hazard identification (the qualitative process of identifying acute and chronic endpoints) and concentration-response assessment (the quantitative relationship between hazard and exposure) for all identified environmental hazard endpoints. Suitable environmental hazard data will be reviewed for acute and chronic endpoints for mortality and other effects (e.g. growth, immobility, reproduction, etc.). EPA will evaluate the character of the concentration-response relationship (i.e. positive, negative or no response) as part of the review.

Sufficient environmental hazard studies are available to assess the hazards of environmental concentrations of perchloroethylene to aquatic species.

- 2) Derive aquatic concentrations of concern (COC) for acute and, where possible, chronic endpoints. The aquatic environmental hazard studies may be used to derive acute and chronic concentrations of concern (COC) for mortality, behavioral, developmental and reproductive or other endpoints determined to be detrimental to environmental populations. Depending on the robustness of the evaluated data for a particular organism (e.g. aquatic invertebrates), environmental hazard values (e.g. ECx/LCx/NOEC/LOEC, etc.) may be derived and used to further understand the hazard characteristics of perchloroethylene to aquatic species.

- 3) Evaluate the weight of the evidence of environmental hazard data. EPA will rely on the weight of the scientific evidence when evaluating and integrating environmental hazard data. The data integration strategy will be designed to be fit-for-purpose. EPA will use systematic review methods to assemble the relevant data, evaluate the data for quality and relevance, including strengths and limitations, followed by synthesis and integration of the evidence. Refer to the supplemental document, *Application of Systematic Review in TSCA Risk Evaluations*, for more information on the general process for data integration.
- 4) Consider the route(s) of exposure, available biomonitoring data and available approaches to integrate exposure and hazard assessments. EPA believes there is sufficient information to evaluate the potential risks to aquatic organisms from exposures to perchloroethylene in ground water and surface water.

#### **2.6.2.2 Human Health Hazards**

EPA expects to consider and analyze human health hazards as follows:

- 1) Review reasonably available human health hazard data, including data from alternative test methods as needed (e.g., computational toxicology and bioinformatics; high-throughput screening methods; data on categories and read-across; *in vitro* studies; systems biology).

For the perchloroethylene risk evaluation, EPA will evaluate information in the IRIS assessment and human health studies using OPPT's structured process described in the document, *Application of Systematic Review in TSCA Risk Evaluations*. Human and animal data will be identified and included as described in the inclusion and exclusion criteria in Appendix F. EPA expects to prioritize the evaluation of mechanistic evidence. Specifically, EPA does not plan to evaluate mechanistic studies unless needed to clarify questions about associations between perchloroethylene and health effects and its relevance to humans. The *Applications of Systematic Review* document describes the process of how studies will be evaluated using specific data evaluation criteria and a predetermined approach. Study results will be extracted and presented in evidence tables by hazard endpoint. EPA expects to evaluate relevant studies identified in the Integrated Risk Information System (IRIS) *Toxicological Review of Tetrachloroethylene* (U.S. EPA, 2012e). In addition, EPA intends to review studies published after the acute reference values were published (e.g. AEGLs) from January 1, 2010 to March 2, 2017 that were captured in the comprehensive literature search conducted by the Agency for perchloroethylene (see *Perchloroethylene (CASRN 127-18-4) Bibliography: Supplemental File for the TSCA Scope Document*) using the approaches described in *Application of Systematic Review in TSCA Risk Evaluations*. To more fully understand circumstances related to deaths by individuals using perchloroethylene, EPA/OPPT will review case reports, case series and ecological studies related to deaths and effects that may imminently lead to death (respiratory distress). EPA/OPPT will not be evaluating case reports and series or ecological studies for endpoints that appear to be less severe endpoints (e.g., nausea).

- 2) In evaluating reasonably available data, determine whether particular human receptor groups may have greater susceptibility to the chemical's hazard(s) than the general population. Reasonably available human health hazard data will be evaluated to ascertain whether some human receptor groups may have greater susceptibility than the general population to perchloroethylene hazard(s).

- 3) Conduct hazard identification (the qualitative process of identifying non-cancer and cancer endpoints) and dose-response assessment (the quantitative relationship between hazard and exposure) for all identified human health hazard endpoints.

Human health hazards from acute and chronic exposures will be identified by evaluating the human and animal data that meet the data quality criteria described in *Application of Systematic Review in TSCA Risk Evaluations*. Data quality evaluation will be performed on relevant studies identified in the IRIS assessment ([U.S. EPA, 2012e](#)), and assessments of the effects of acute exposures in the ([NAC/AEGL](#)). Data quality evaluation will also be performed on studies that were identified in the comprehensive literature search and that met the inclusion criteria for full-text screening (see *Application of Systematic Review in TSCA Risk Evaluations*. Hazards identified by studies meeting data quality criteria will be grouped by routes of exposure relevant to humans (oral, inhalation) and by cancer and noncancer endpoints.

Dose-response assessment will be performed in accordance with EPA guidance ([U.S. EPA, 2012a, 2011, 1994](#)). Dose-response analyses performed to support the IRIS oral and inhalation reference dose determinations and for the cancer unit risk and slope factor ([U.S. EPA, 2012e](#)) may be used if the data meet data quality criteria and if additional information on the identified hazard endpoints or additional hazard endpoints would not alter the analysis.

- 4) Derive points of departure (PODs) where appropriate; conduct benchmark dose modeling depending on the available data. Adjust the PODs as appropriate to conform (e.g., adjust for duration of exposure) to the specific exposure scenarios evaluated.

Hazard data will be evaluated to determine the type of dose-response modeling that is applicable, if the dose-response modeling requires updating. Where modeling is feasible, a set of dose-response models that are consistent with a variety of potentially underlying biological processes will be applied to empirically model the dose-response relationships in the range of the observed data consistent with the EPA *Benchmark Dose Technical Guidance Document*. Where dose-response modeling is not feasible, NOAELs or LOAELs will be identified.

EPA will evaluate whether the available PBPK and empirical kinetic models are adequate for route-to-route and interspecies extrapolation of the POD, or for extrapolation of the POD to appropriate exposure durations for the risk evaluation.

- 5) Consider the route(s) of exposure (oral, inhalation, dermal), available route-to-route extrapolation approaches, available biomonitoring data and available approaches to correlate internal and external exposures to integrate exposure and hazard assessment.

EPA believes there are sufficient data to conduct dose-response analysis with benchmark dose modeling or NOAELs or LOAELs for both inhalation and oral routes of exposure.

A route-to-route extrapolation from the inhalation and oral toxicity studies is needed to assess systemic risks from dermal exposures. Without an adequate PBPK model, the approaches described in the EPA guidance document *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* could be applied. These approaches may be able to further inform the relative importance of dermal exposures compared with other routes of exposure.

- 6) Evaluate the weight of the evidence of human health hazard data. EPA will rely on the weight of the scientific evidence when evaluating and integrating human health hazard data. The data integration strategy will be designed to be fit-for-purpose in which EPA will use systematic review methods to assemble the relevant data, evaluate the data for quality and relevance, including strengths and limitations, followed by synthesis and integration of the evidence. Refer to the *Systematic Review Approaches and Methods Applied to TSCA Risk Evaluations* document for more information on the general process for data evaluation.

### **2.6.3 Risk Characterization**

Risk characterization is an integral component of the risk assessment process for both ecological and human health risks. EPA will derive the risk characterization in accordance with EPA's *Risk Characterization Handbook* (U.S. EPA, 2000a). As defined in EPA's *Risk Characterization Policy*, "the risk characterization integrates information from the preceding components of the risk evaluation and synthesizes an overall conclusion about risk that is complete, informative and useful for decision makers." Risk characterization is considered to be a conscious and deliberate process to bring all important considerations about risk, not only the likelihood of the risk, but also the strengths and limitations of the assessment, and a description of how others have assessed the risk into an integrated picture.

Risk characterization at EPA assumes different levels of complexity depending on the nature of the risk assessment being characterized. The level of information contained in each risk characterization varies according to the type of assessment for which the characterization is written. Regardless of the level of complexity or information, the risk characterization for TSCA risk evaluations will be prepared in a manner that is transparent, clear, consistent, and reasonable (TCCR) (U.S. EPA, 2000a). EPA will also present information in this section consistent with approaches described in the Procedures for Chemical Risk Evaluation Under the Amended Toxic Substances Control Act Risk Evaluation Framework Rule (82 FR 33726). For instance, in the risk characterization summary, EPA will further carry out the obligations under TSCA section 26; for example, by identifying and assessing uncertainty and variability in each step of the risk evaluation, discussing considerations of data quality such as the reliability, relevance and whether the methods utilized were reasonable and consistent, explaining any assumptions used, and discussing information generated from independent peer review. EPA will also be guided by EPA's Information Quality Guidelines (U.S. EPA, 2002) as it provides guidance for presenting risk information. Consistent with those guidelines, in the risk characterization, EPA will also identify: (1) Each population addressed by an estimate of applicable risk effects; (2) the expected risk or central estimate of risk for the potentially exposed or susceptible subpopulations affected; (3) each appropriate upper-bound or lower bound estimate of risk; (4) each significant uncertainty identified in the process of the assessment of risk effects and the studies that would assist in resolving the uncertainty; and (5) peer reviewed studies known to the Agency that support, are directly relevant to, or fail to support any estimate of risk effects and the methodology used to reconcile inconsistencies in the scientific information.

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# APPENDICES

## Appendix A REGULATORY HISTORY

### A.1 Federal Laws and Regulations

**Table Apx A-1. Federal Laws and Regulations**

Statutes/Regulations	Description of Authority/Regulation	Description of Regulation
<b>EPA Regulations</b>		
Toxics Substances Control Act (TSCA) – Section 6(b)	EPA is directed to identify and begin risk evaluations on 10 chemical substances drawn from the 2014 update of the TSCA Work Plan for Chemical Assessments.	Perchloroethylene is on the initial list of chemicals to be evaluated for unreasonable risk under TSCA (81 FR 91927, December 19, 2016).
Toxics Substances Control Act (TSCA) – Section 8(a)	The TSCA Section 8(a) Chemical Data Reporting (CDR) Rule requires manufacturers (including importers) to give EPA basic exposure-related information on the types, quantities and uses of chemical substances produced domestically and imported into the United States.	Perchloroethylene manufacturing (including importing), processing, and use information is reported under the Chemical Data Reporting (CDR) rule (76 FR 50816, August 16, 2011).
Toxics Substances Control Act (TSCA) – Section 8(b)	EPA must compile, keep current, and publish a list (the TSCA Inventory) of each chemical substance manufactured, processed or imported in the United States.	Perchloroethylene was on the initial TSCA Inventory and therefore was not subject to EPA's new chemicals review process (76 FR 50816, August 16, 2011).
Toxics Substances Control Act (TSCA) – Section 8(e)	Manufacturers (including imports), processors, and distributors must immediately notify EPA if they obtain information that supports the conclusion that a chemical substance or mixture presents a substantial risk of injury to health or the environment.	Eleven risk reports received for perchloroethylene (1978-2010) (US EPA, ChemView. Accessed April 13, 2017).
Toxics Substances Control Act (TSCA) – Section 4	Provides EPA with authority to issue rules and orders requiring manufacturers (including importers) and processors to test chemical substances and mixtures.	Nine chemical data submissions from test rules received for perchloroethylene (1978-1980) (US EPA, ChemView. Accessed April 13, 2017).
Emergency Planning and Community Right-to-Know Act (EPCRA) – Section 313	Requires annual reporting from facilities in specific industry sectors that employ 10 or more full time equivalent employees and that manufacture, process or otherwise use a	Perchloroethylene is a listed substance subject to reporting requirements under 40 CFR 372.65 effective as of January 1, 1987.

Statutes/Regulations	Description of Authority/Regulation	Description of Regulation
	TRI-listed chemical in quantities above threshold levels.	
Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) - Sections 3 and 6	FIFRA governs the sale, distribution and use of pesticides. Section 3 of FIFRA generally requires that pesticide products be registered by EPA prior to distribution or sale. Pesticides may only be registered if, among other things, they do not cause “unreasonable adverse effects on the environment.” Section 6 of FIFRA provides EPA with the authority to cancel pesticide registrations if either (1) the pesticide, labeling or other material does not comply with FIFRA; or (2) when used in accordance with widespread and commonly recognized practice, the pesticide generally causes unreasonable adverse effects on the environment.	EPA removed perchloroethylene and other chemical substances from its list of pesticide product inert ingredients used in pesticide products (63 FR 34384, June 24, 1998).
Clean Air Act (CAA) – Section 112(b)	Defines the original list of 189 hazardous air pollutants (HAP). Under 112(c) of the CAA, EPA must identify and list source categories that emit HAP and then set emission standards for those listed source categories under CAA section 112(d). CAA section 112(b)(3)(A) specifies that any person may petition the Administrator to modify the list of HAP by adding or deleting a substance. Since 1990 EPA has removed two pollutants from the original list leaving 187 at present.	Lists perchloroethylene as a Hazardous Air Pollutant (42 U.S. Code § 7412), and is considered an “urban air toxic” (CAA Section 112(k)).
Clean Air Act (CAA) – Section 112(d)	Section 112(d) states that the EPA must establish national emission standards for HAP (NESHAP) for each category or subcategory of major sources and area sources of HAPs [listed pursuant to Section 112(c)]. The standards must require the maximum degree of emission reduction that the EPA determines to be achievable by each particular source category. Different criteria for maximum achievable control technology (MACT) apply for new and existing sources. Less stringent	There are a number of source-specific CAA, Section 112, NESHAPs for perchloroethylene, including: Dry cleaners (73 FR 39871, July 11, 2008) Organic liquids distribution (non-gasoline) (69 FR 5038, February 3, 2004) Off-site waste and recovery operations (64 FR 38950, July 20, 1999) Rubber Tire Manufacturing (67 FR 45588, July 9, 2002)

Statutes/Regulations	Description of Authority/Regulation	Description of Regulation
	standards, known as generally available control technology (GACT) standards, are allowed at the Administrator's discretion for area sources.	Wood furniture manufacturing (60 FR 62930, December 7, 1995) Synthetic organic chemical manufacturing (59 FR 19402, April 22, 1994) Chemical Manufacturing Area Source Categories (74 FR 56008, October 29, 2009) Publicly Owned Treatment Works (64 FR 57572, October 26, 1999) Site Remediation includes perchloroethylene (68 FR 58172, October 8, 2003)
Clean Air Act (CAA) – Section 112(d) and 112(f)	Risk and technology review (RTR) of section 112(d) MACT standards. Section 112(f)(2) requires EPA to conduct risk assessments for each source category subject to section 112(d) MACT standards, and to determine if additional standards are needed to reduce remaining risks. Section 112(d)(6) requires EPA to review and revise the MACT standards, as necessary, taking into account developments in practices, processes and control technologies.”	EPA has promulgated a number of RTR NESHAP (e.g., the RTR NESHAP for Perchloroethylene Dry Cleaning (71 FR 42724; July 27, 2006) and the RTR NESHAP for Halogenated Solvent Cleaning (72 FR 25138; May 3, 2007) and will do so, as required, for the remaining source categories with NESHAP
Clean Air Act (CAA) – Section 183(e)	Section 183(e) requires EPA to list the categories of consumer and commercial products that account for at least 80 percent of all VOC emissions in areas that violate the National Ambient Air Quality Standards (NAAQS) for ozone and to issue standards for these categories that require “best available controls.” In lieu of regulations, EPA may issue control techniques guidelines if the guidelines are determined to be substantially as effective as regulations.	Perchloroethylene is listed under the National Volatile Organic Compound Emission Standards for Aerosol Coatings (40 CFR part 59, subpart E). Perchloroethylene has a reactivity factor of 0.04g O3/g VOC.
Clean Air Act (CAA) – Section 612	Under Section 612 of the Clean Air Act (CAA), EPA’s Significant New Alternatives Policy (SNAP) program reviews substitutes for ozone depleting substances within a comparative risk framework. EPA publishes lists of acceptable and unacceptable alternatives. A determination that an	Under the SNAP program, EPA listed perchloroethylene as an acceptable substitute in cleaning solvent for metal cleaning, electronics cleaning and precision cleaning (59 FR 13044, March 18, 1994). Perchloroethylene is cited as an alternative to methyl chloroform and CFC-113 for metals,

Statutes/Regulations	Description of Authority/Regulation	Description of Regulation
	alternative is unacceptable or acceptable only with conditions, is made through rulemaking.	electronics and precision cleaning. Perchloroethylene was also noted to have no ozone depletion potential and cited as a VOC-exempt solvent and acceptable ozone-depleting substance substitute (72 FR 30142, May 30, 2007).
Clean Water Act (CWA) – Section 301(b), 304(b), 306, and 307(b)	Requires establishment of Effluent Limitations Guidelines and Standards for conventional, toxic, and non-conventional pollutants. For toxic and non-conventional pollutants, EPA identifies the best available technology that is economically achievable for that industry after considering statutorily prescribed factors and sets regulatory requirements based on the performance of that technology.	Perchloroethylene is designated as a toxic pollutant under section 307(a)(1) of CWA and as such is subject to effluent limitations. Also under section 304, perchloroethylene is included in the list of total toxic organics (TTO) (40 CFR 413.02(i)).
Clean Water Act (CWA) 304(a)	Section 304(a)(1) of the Clean Water Act (CWA) requires EPA to develop and publish, and from time to time revise, recommended criteria for the protection of water quality that accurately reflect the latest scientific knowledge. Water quality criteria developed under section 304(a) are based solely on data and scientific judgments on the relationship between pollutant concentrations and environmental and human health effects.	
Clean Water Act (CWA) – Section 307(a)	Establishes a list of toxic pollutants or combination of pollutants under the CWA. The statute specifies a list of families of toxic pollutants also listed in the Code of Federal Regulations at 40 CFR 401.15. The “priority pollutants” specified by those families are listed in 40 CFR part 423, Appendix A. These are pollutants for which best available technology effluent limitations must be established on either a national basis through rules (Sections 301(b), 304(b), 307(b), 306), or on a case-by-case best professional judgement basis in NPDES permits (Section 402(a)(1)(B)).	

Statutes/Regulations	Description of Authority/Regulation	Description of Regulation
Safe Drinking Water Act (SDWA) – Section 1412	Requires EPA to publish a non-enforceable maximum contaminant level goals (MCLGs) for contaminants which 1. may have an adverse effect on the health of persons; 2. are known to occur or there is a substantial likelihood that the contaminant will occur in public water systems with a frequency and at levels of public health concern; and 3. in the sole judgment of the Administrator, regulation of the contaminant presents a meaningful opportunity for health risk reductions for persons served by public water systems. When EPA publishes an MCLG, EPA must also promulgate a National Primary Drinking Water Regulation (NPDWR) which includes either an enforceable maximum contaminant level (MCL) or a required treatment technique. Public water systems are required to comply with NPDWRs	Perchloroethylene is subject to National Primary Drinking Water Regulations (NPDWR) under SDWA with a MCLG of zero and an enforceable maximum contaminant level (MCL) of 0.005 mg/L (40 CFR 141.61). On January 11, 2017, EPA announced a review of the eight existing NPDWRs (82 FR 3518). Perchloroethylene is one of the eight NPDWRs. EPA requested comment on the eight NPDWRs identified as candidates for revision.
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) – Section 102(a) and 103	<p>Authorizes EPA to promulgate regulations designating as hazardous substances those substances which, when released into the environment, may present substantial danger to the public health or welfare or the environment. EPA must also promulgate regulations establishing the quantity of any hazardous substance the release of which must be reported under Section 103.</p> <p>Section 103 requires persons in charge of vessels or facilities to report to the National Response Center if they have knowledge of a release of a hazardous substance above the reportable quantity threshold.</p>	Perchloroethylene is a hazardous substance under CERCLA. Releases of perchloroethylene in excess of 100 pounds must be reported (40 CFR 302.4).
Resource Conservation and Recovery Act (RCRA) – Section 3001	Directs EPA to develop and promulgate criteria for identifying the characteristics of hazardous waste, and for listing hazardous waste, taking into account toxicity, persistence, and	Perchloroethylene is included on the list of hazardous wastes pursuant to RCRA 3001. RCRA Hazardous Waste Code: D039 at 0.7 mg/L; F001, F002; U210.

Statutes/Regulations	Description of Authority/Regulation	Description of Regulation
	degradability in nature, potential for accumulation in tissue, and other related factors such as flammability, corrosiveness, and other hazardous characteristics.	In 2013, EPA modified its hazardous waste management regulations to conditionally exclude solvent-contaminated wipes that have been cleaned and reused from the definition of solid waste under RCRA (78 FR 46447, July 31, 2013).
Superfund Amendments and Reauthorization Act (SARA) –	Requires the Agency to revise the hazardous ranking system and update the National Priorities List of hazardous waste sites, increases state and citizen involvement in the superfund program and provides new enforcement authorities and settlement tools.	Perchloroethylene is listed on SARA, an amendment to CERCLA and the CERCLA Priority List of Hazardous Substances. This list includes substances most commonly found at facilities on the CERCLA National Priorities List (NPL) that have been deemed to pose the greatest threat to public health.
<b>Other Federal Regulations</b>		
Federal Hazardous Substance Act (FHSA)	Allows the Consumer Product Safety Commission (CPSC) to (1) require precautionary labeling on the immediate container of hazardous household products or (2) to ban certain products that are so dangerous or the nature of the hazard is such that required labeling is not adequate to protect consumers.	Under the Federal Hazardous Substance Act, section 1500.83(a)(31), visual novelty devices containing perchloroethylene are regulated by CPSC.
Federal Food, Drug, and Cosmetic Act (FFDCA)	Provides the U.S. FDA (Food and Drug Administration) with authority to oversee the safety of food, drugs and cosmetics.	The FDA regulates perchloroethylene in bottled water. The maximum permissible level of perchloroethylene in bottled water is 0.005 mg/L (21 CFR 165.110).
Occupational Safety and Health Act (OSH Act)	Requires employers to provide their workers with a place of employment free from recognized hazards to safety and health, such as exposure to toxic chemicals, excessive noise levels, mechanical dangers, heat or cold stress or unsanitary conditions. Under the Act, the Occupational Safety and Health Administration can issue occupational safety and health standards including such provisions as Permissible Exposure Limits (PELs), exposure	In 1970, OSHA issued occupational safety and health standards for perchloroethylene that included a Permissible Exposure Limit (PEL) of 100 ppm TWA, exposure monitoring, control measures and respiratory protection (29 CFR 1910.1000).

Statutes/Regulations	Description of Authority/Regulation	Description of Regulation
	monitoring, engineering and administrative control measures and respiratory protection.	
Atomic Energy Act Department of Energy (DOE)	The Atomic Energy Act authorizes DOE to regulate the health and safety of its contractor employees	10 CFR 851.23, Worker Safety and Health Program, requires the use of the 2005 ACGIH TLVs if they are more protective than the OSHA PEL. The 2005 TLV for perchloroethylene is 25 ppm (8hr Time Weighted Average) and 100 ppm Short Term Exposure Limit(STEL).

## A.2 State Laws and Regulations

**Table\_Apx A-2. State Laws and Regulations**

State Actions	Description of Action
<b>State actions</b>	
State Permissible Exposure Limits	California has a workplace PEL of 25 ppm (California, OEHHA, 1988)
State Right-to-Know Acts	Massachusetts (454 CMR 21.00), New Jersey (42 N.J.R 1709(a)), Pennsylvania (Chapter 323, Hazardous Substance List), Rhode Island (RI Gen. Laws Sec. 28-21-1 et seq).
Volatile Organic Compound (VOC) Regulations for Consumer Products	Many states regulate perchloroethylene as a VOC. These regulations may set VOC limits for consumer products and/or ban the sale of certain consumer products as an ingredient and/or impurity. Regulated products vary from state to state, and could include contact and aerosol adhesives, aerosols, electronic cleaners, footwear or leather care products, and general degreasers, among other products. California (Title 17, California Code of Regulations, Division 3, Chapter 1, Subchapter 8.5, Articles 1, 2, 3 and 4), Connecticut (R.C.S.A Sections 22a-174-40, 22a-174-41, and 22a-174-44), Delaware (Adm. Code Title 7, 1141), District of Columbia (Rules 20-720, 20-721, 20-735, 20-736, 20737), Illinois (35 Adm Code 223), Indiana ( 326 IAC 8-15), Maine (Chapter 152 of the Maine Department of Environmental Protection Regulations), Maryland (COMAR 26.11.32.00 to 26.11.32.26), Michigan (R 336.1660 and R 336. 1661), New Hampshire (Env--A 4100) New Jersey (Title 7, Chapter 27, Subchapter 24), New York (6 CRR-NY III A 235), Rhode Island (Air Pollution Control Regulation No. 31), and Virginia (9VAC5 CHAPTER 45) all have VOC regulations or limits for consumer products. Some of these states also require emissions reporting.
Other	There are several state level NESHAPs for dry cleaning and restrictions or phase outs of perchloroethylene (e.g. California, Maine, Massachusetts). Numerous states list perchloroethylene on a list of chemical substances of high concern to children (e.g. Oregon, Vermont, Washington). Under the California Proposition 65 list

State Actions	Description of Action
	(California OEHHA), perchloroethylene is known to the state of California to cause cancer.

### A.3 International Laws and Regulations

**Table\_Apx A-3. Regulatory Actions by Other Governments and Tribes**

Country/Organization	Requirements and Restrictions
Canada	Perchloroethylene is on the Canadian List of Toxic Substances (CEPA 1999 Schedule 1). The use and sale of perchloroethylene in the dry cleaning industry is regulated under <i>Use in Dry Cleaning and Reporting Requirements Regulations</i> (Canada Gazette, Part II on March 12, 2003). Perchloroethylene is also regulated for use and sale for solvent degreasing under Solvent Degreasing Regulations (SOR/2003-283) (Canada Gazette, Part II on August 13, 2003). The purpose of the regulation is to reduce releases of perchloroethylene into the environment from solvent degreasing facilities using more than 1,000 kilograms of perchloroethylene per year. The regulation includes a market intervention by establishing tradable allowances for the use of perchloroethylene in solvent degreasing operations that exceed the 1,000 kilograms threshold per year.
European Union	Perchloroethylene was evaluated under the 2013 Community Rolling Action Plan (CoRAP). The conclusion was no additional regulatory action was required (European Chemicals Agency (ECHA) database. Accessed April, 18 2017).
Australia	In 2011, a preliminary assessment of perchloroethylene was conducted (National Industrial Chemicals Notification and Assessment Scheme, NICNAS, 2016, Tetrachloroethylene. Accessed April, 18 2017).
Japan	<p>Perchloroethylene is regulated in Japan under the following legislation:</p> <ul style="list-style-type: none"> <li>• Act on the Evaluation of Chemical Substances and Regulation of Their Manufacture, etc. (Chemical Substances Control Law; CSCL)</li> <li>• Act on Confirmation, etc. of Release Amounts of Specific Chemical Substances in the Environment and Promotion of Improvements to the Management Thereof</li> <li>• Industrial Safety and Health Act (ISHA)</li> <li>• Air Pollution Control Law</li> <li>• Water Pollution Control Law</li> <li>• Soil Contamination Countermeasures Act</li> <li>• Law for the Control of Household Products Containing Harmful Substances</li> </ul> <p>(National Institute of Technology and Evaluation (NITE) Chemical Risk Information Platform (CHIRP). Accessed April 18, 2017)</p>
Australia, Austria, Belgium, Canada, Denmark, European Union, Finland, France,	Occupational exposure limits for perchloroethylene (GESTIS International limit values for chemical agents (Occupational exposure limits, OELs) database. Accessed April 18, 2017).

Country/Organization	Requirements and Restrictions
Germany, Hungary, Ireland, Israel, Japan, Latvia, New Zealand, People's Republic of China, Poland, Singapore, South Korea, Spain, Sweden, Switzerland, United Kingdom	
Basel Convention	Halogenated organic solvents (Y41) are listed as a category of waste under the Basel Convention – Annex I. Although the United States is not currently a party to the Basel Convention, this treaty still affects U.S. importers and exporters.
OECD Control of Transboundary Movements of Wastes Destined for Recovery Operations	Halogenated organic solvents (A3150) are listed as a category of waste subject to The Amber Control Procedure under Council Decision C (2001) 107/Final.

## Appendix B PROCESS, RELEASE AND OCCUPATIONAL EXPOSURE INFORMATION

This appendix provides information and data found in preliminary data gathering for perchloroethylene.

### B.1 Process Information

Process-related information potentially relevant to the risk evaluation may include process diagrams, descriptions and equipment. Such information may inform potential release sources and worker exposure activities. EPA will consider this information in combination with available monitoring data and estimation methods and models, as appropriate, to quantify occupational exposure and releases for the various conditions of use in the risk evaluation.

#### B.1.1 Manufacture (Including Import)

##### B.1.1.1 Domestic Manufacture

Perchloroethylene was previously produced through chlorination of acetylene to tetrachloroethane, then dehydrochlorination to trichloroethylene (TCE), followed by chlorination of TCE to pentachloroethane and finally dehydrochlorination to perchloroethylene (Snedecor et al., 2004). The last U.S. plant using the acetylene process was shut down in 1978 (Snedecor et al., 2004). Currently, most perchloroethylene is manufactured using one of three methods: chlorination of ethylene dichloride (EDC); chlorination of hydrocarbons containing one to three carbons (C1 to C3) or their partially chlorinated derivatives; or oxychlorination of two-carbon (C2) chlorinated hydrocarbons (ATSDR, 2014; Snedecor et al., 2004; U.S. EPA, 1985b).

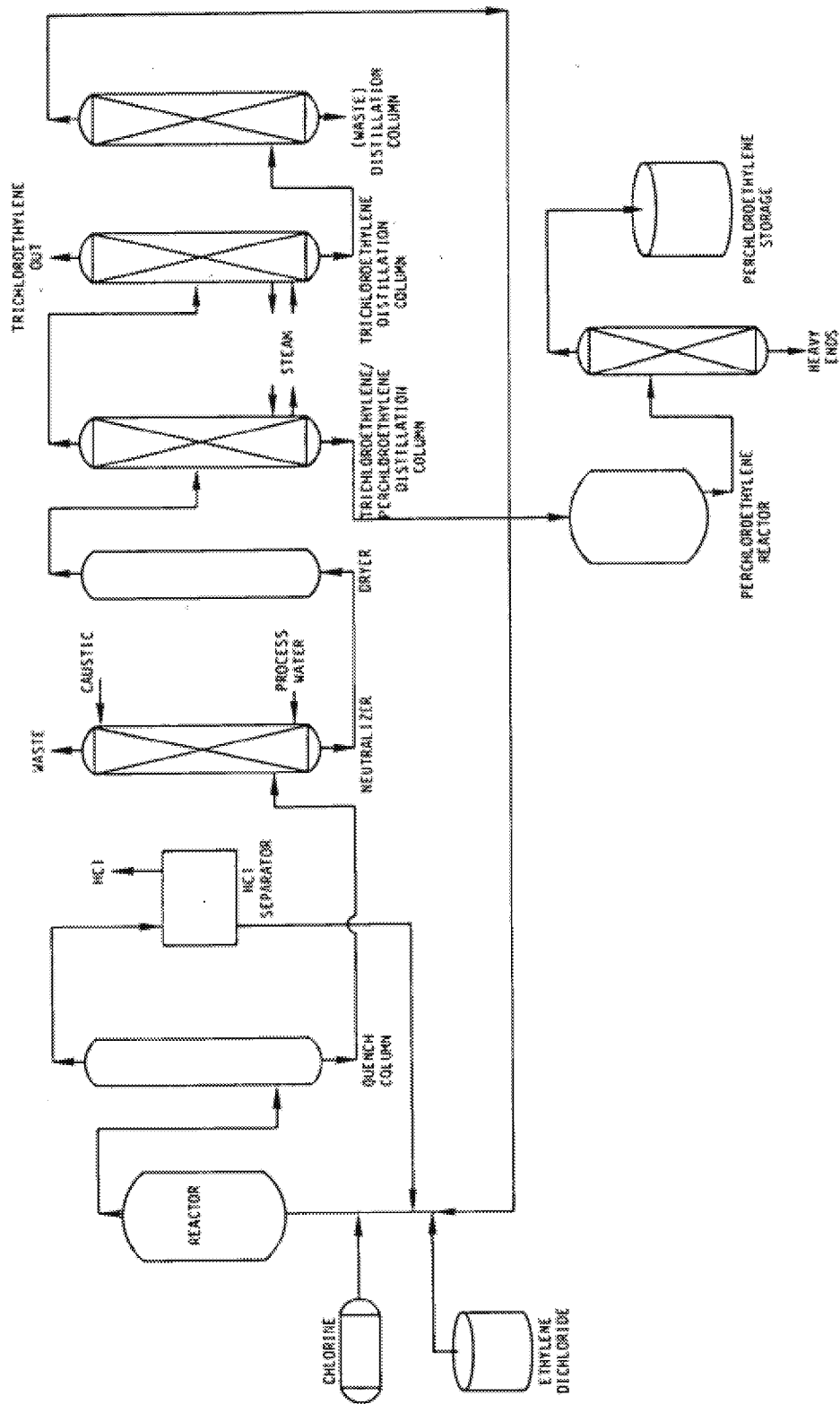
**Chlorination of EDC** – The chlorination of EDC involves a non-catalytic reaction of chlorine and EDC or other C2 chlorinated hydrocarbons to form perchloroethylene and TCE as co-products and hydrochloric acid (HCl) as a byproduct (ATSDR, 2014; Snedecor et al., 2004; U.S. EPA, 1985b). Following reaction, the product undergoes quenching, HCl separation, neutralization, drying and distillation (U.S. EPA, 1985b). This process is advantageous at facilities that have a feedstock source of mixed C2 chlorinated hydrocarbons from other processes and an outlet for the HCl byproduct (Snedecor et al., 2004). Figure\_Apx B-1 illustrates a typical process diagram of the production of perchloroethylene via EDC chlorination (U.S. EPA, 1985b).

**Chlorination of C1-C3 hydrocarbons** – The chlorination of C1-C3 hydrocarbons involves the reaction of chlorine with a hydrocarbon such as methane, ethane, propane, propylene or their chlorinated derivatives, at high temperatures (550–700°C), with or without a catalyst, to form perchloroethylene and carbon tetrachloride (CCl<sub>4</sub>) as co-products and HCl as a byproduct (ATSDR, 2014; Snedecor et al., 2004; U.S. EPA, 1985b). This process is advantageous because mixed chlorinated hydrocarbon wastes from other processes can be used as a feedstock (ATSDR, 2014; (Snedecor et al., 2004)). Due to phase-out of CFC-11 and CFC-12 and most CCl<sub>4</sub> uses, most facilities using this method maximize the production of perchloroethylene and minimize or eliminate the production of CCl<sub>4</sub> (Snedecor et al., 2004). Figure\_Apx B-2 illustrates a typical process diagram of the production of perchloroethylene via C1-C3 hydrocarbon chlorination (U.S. EPA, 1985b).

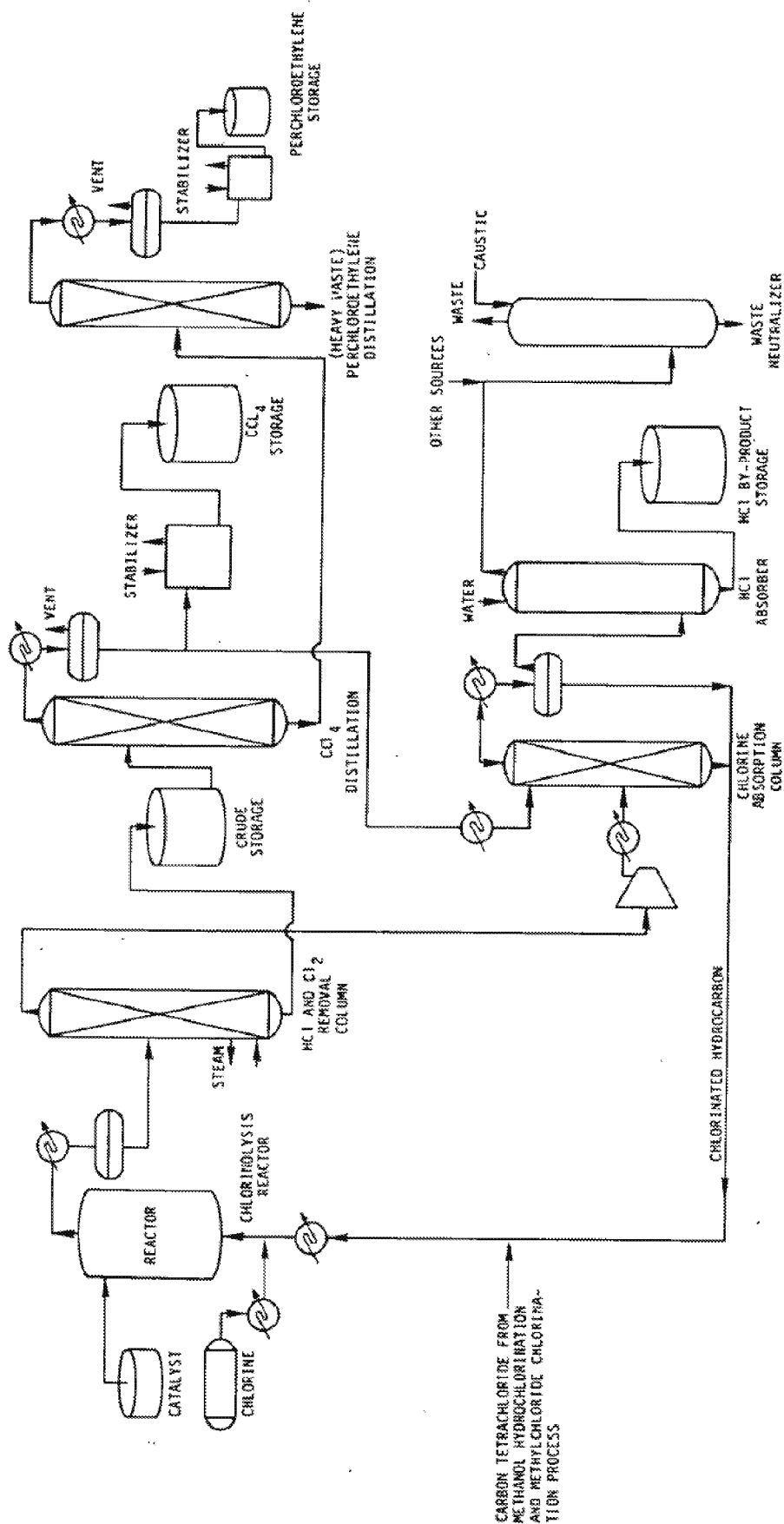
**Oxychlorination of C2 chlorinated hydrocarbons** – The oxychlorination of C2 chlorinated hydrocarbons involves the reaction of either chlorine or HCl and oxygen with EDC in the presence of a catalyst to produce perchloroethylene and TCE as co-products (ATSDR, 2014; Snedecor et al., 2004). Following reaction, the product undergoes HCl separation, drying, distillation, neutralization with ammonia and a final drying step (U.S. EPA, 1985b). The advantage of this process is that no byproduct

HCl is produced and can be combined with other processes as a net HCl consumer ([ATSDR, 2014](#); [Snedecor et al., 2004](#)). Figure\_Apx B-3 illustrates a typical process diagram of the production of perchloroethylene via oxychlorination of C2 hydrocarbons ([U.S. EPA, 1985b](#)).

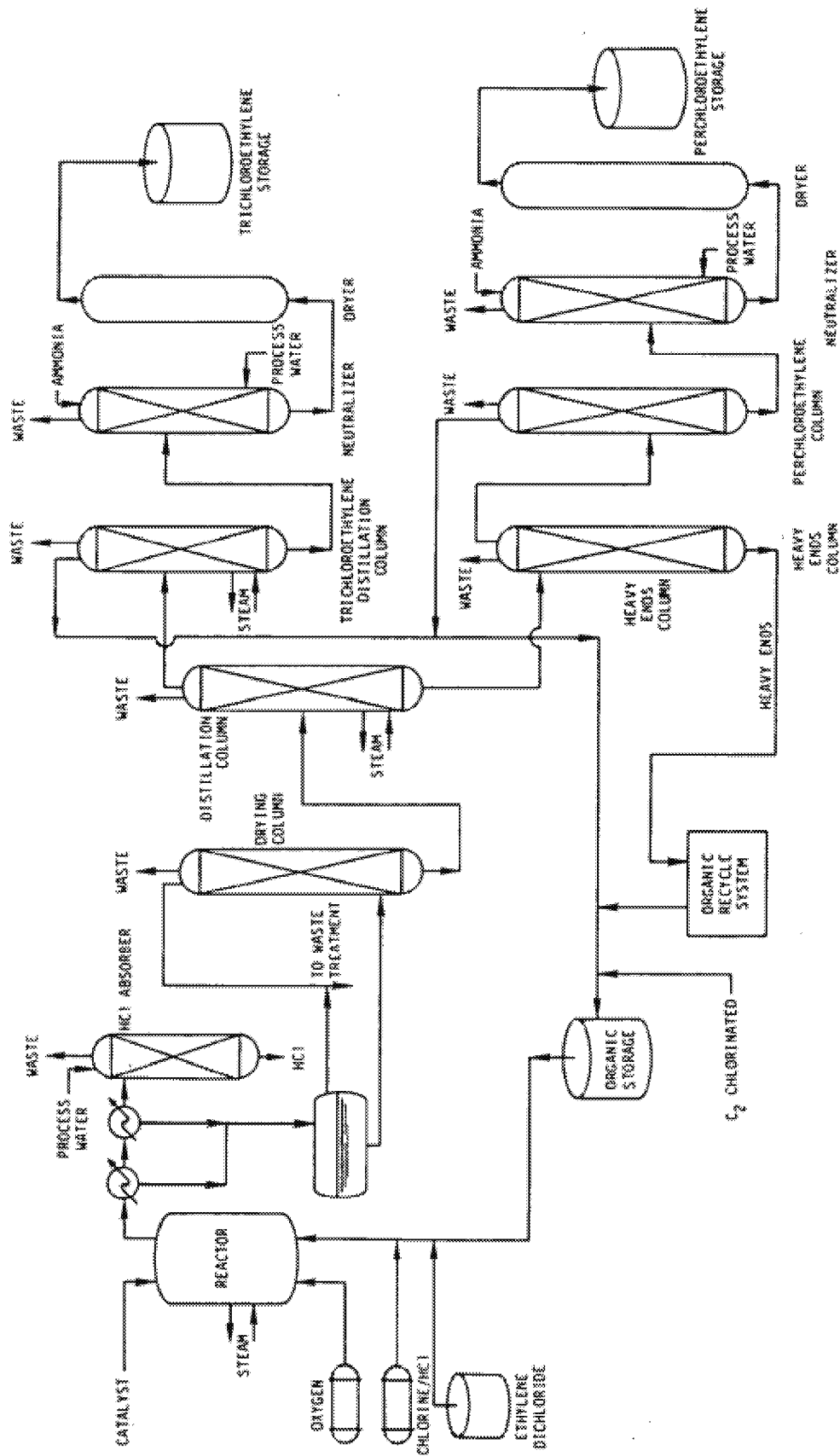
In all three processes the product ratio of perchloroethylene to TCE/ $\text{CCl}_4$  products are controlled by adjusting the reactant ratios ([Snedecor et al., 2004](#)).



Figure\_Apx B-1. Process Flow Diagram for the Manufacture of Perchloroethylene via Chlorination of EDC (EPA, 1985)



Figure\_Apx B-2. Process Flow Diagram for the Manufacture of Perchloroethylene via Chlorination of Hydrocarbons (EPA, 1985)



Figure\_Apx B-3. Process Flow Diagram for the Manufacture of Perchloroethylene via Oxychlorination of C2 Chlorinated Hydrocarbons (EPA, 1985)

### **B.1.1.2 Import**

According to [Snedecor et al. \(2004\)](#), perchloroethylene may be shipped by barge, tank car, tank truck or 55-gallon steel drums. Perchloroethylene may be stored in steel tanks that are dry, free of rust and equipped with a chemical vent dryer and controlled evaporation vent ([Snedecor et al., 2004](#)).

### **B.1.2 Processing and Distribution**

Based on the reported industrial processing operations in the 2016 CDR, perchloroethylene may be incorporated into a variety of formulations, products and articles, or used industrially as a chemical intermediate ([U.S. EPA, 2016b](#)). Some industrial or commercial products may also be repackaged into appropriately-sized containers to meet specific customer demands ([U.S. EPA, 2016b](#)).

#### **B.1.2.1 Reactant or Intermediate**

Processing as a reactant or intermediate is the use of perchloroethylene as a feedstock in the production of another chemical product via a chemical reaction in which perchloroethylene is consumed to form the product. In the past, perchloroethylene was used as feedstock (with chlorine) for the manufacture of one- and two-carbon (C1 and C2) CFCs ([Smart and Fernandez, 2000](#)). However, due to discovery that CFCs contribute to stratospheric ozone depletion, the use of CFCs was phased-out by the year 2000 to comply with the Montreal Protocol ([Smart and Fernandez, 2000](#)). Since the phase-out of CFCs, perchloroethylene has been used to manufacture the CFC alternatives, HCFCs, specifically the HCFC-123 alternative to CFC-11 ([Smart and Fernandez, 2000](#)). Perchloroethylene is also used as a feedstock in the production of trichloroacetyl chloride ([Smart and Fernandez, 2000](#)).

HCFC-123 is produced by fluorination of perchloroethylene with liquid or gaseous hydrofluoric acid (HF). The manufacture of HCFC is more complex than the manufacture of CFCs due to potential byproduct formation or catalyst inactivation caused by the extra hydrogen atom in the HCFCs ([Smart and Fernandez, 2000](#)). Therefore, the process involved in the manufacture of HCFCs requires additional reaction and distillation steps as compared to the CFC manufacturing process ([Smart and Fernandez, 2000](#)).

Perchloroethylene is also used by Honeywell International Inc. in the manufacture of HFC-125 (R-125), HCFC-124 (R-124), and CFC-113 (R-113) ([Honeywell, 2017](#)). In 2016, Honeywell used approximately 65 million pounds of perchloroethylene to manufacture R-125 and R-124 and approximately 20 million pounds to manufacture R-113 ([Honeywell, 2017](#)). The majority of the R-113 is used as an intermediate for manufacture of chlorotrifluoroethylene (CTFE) monomer; however, a small portion is used in exempted applications vital to U.S. security ([Honeywell, 2017](#)). Perchloroethylene is received at the Honeywell facilities in railcars and trucks and is transferred into storage vessels with a pump and vapor balance ([Honeywell, 2017](#)). Some perchloroethylene is lost when disconnecting the hose; however, the storage tank is pressurized so there are no point emissions or breathing losses ([Honeywell, 2017](#)). The primary emission of perchloroethylene at Honeywell facilities are from fugitive emissions. The facilities utilize a fugitive emissions monitoring program and leak detection program to reduce fugitive emissions ([Honeywell, 2017](#)).

Honeywell representatives indicated that the R-125/R-124 processes achieve a once through perchloroethylene conversion of 95% and the remaining 5% is recovered and recycled back into the process ([Honeywell, 2017](#)). For the R-113 process, the once through conversion rate is 99% and the remaining 1% is recovered and recycled back into the process ([Honeywell, 2017](#)). The ultimate conversion from both processes is 100%. Honeywell indicated they do not detect any perchloroethylene in their products ([Honeywell, 2017](#)).

Perchloroethylene is also used in catalyst regeneration at petroleum refineries (Dow Chemical Co., 2008; Public Comment, EPA-HQ-OPPT-2016-0732-0018). Perchloroethylene is consumed in the catalyst regeneration process; therefore, EPA considers this use as a reactant/intermediate. According to public comments from the American Fuel and Petrochemical Manufacturers (AFPM) (Public Comment, EPA-HQ-OPPT-2016-0732-0018), perchloroethylene is used in both the reforming and isomerization processes at refineries. In the reforming process, perchloroethylene is added directly to a regenerator in a Continuous Catalytic Regeneration reforming unit, and in the isomerization process, perchloroethylene is added to the hydrocarbon feed (Public Comment, EPA-HQ-OPPT-2016-0732-0018). In both processes, perchloroethylene provides chlorine ions to regenerate the catalysts and is consumed in the process (Public Comment, EPA-HQ-OPPT-2016-0732-0018).

#### **B.1.2.2 Incorporating into a Formulation, Mixture or Reaction Product**

Incorporation into a formulation, mixture or reaction product refers to the process of mixing or blending of several raw materials to obtain a single product or preparation. The uses of perchloroethylene that may require incorporation into a formulation include adhesives, sealants, coatings, inks, lubricants and plastic and rubber manufacturing. Perchloroethylene specific formulation processes were not identified; however, several ESDs published by the OECD and Generic Scenarios published by EPA have been identified that provide general process descriptions for these types of products.

The formulation of coatings and inks typically involves dispersion, milling, finishing and filling into final packages (OECD, 2009c; U.S. EPA, 2001b). Adhesive formulation involves mixing together volatile and non-volatile chemical components in sealed, unsealed or heated processes (OECD, 2009a). Sealed processes are most common for adhesive formulation because many adhesives are designed to set or react when exposed to ambient conditions (OECD, 2009a). Lubricant formulation typically involves the blending of two or more components, including liquid and solid additives, together in a blending vessel (OECD, 2004a). In plastics and rubber manufacturing the formulation step usually involves the compounding of the polymer resin with additives and other raw materials to form a masterbatch in either open or closed blending processes (U.S. EPA, 2014b; OECD, 2009b). After compounding, the resin is fed to an extruder where it is converted into pellets, sheets, films or pipes (U.S. EPA, 2014b).

#### **B.1.2.3 Incorporating into an Article**

Incorporation into an article typically refers to a process in which a chemical becomes an integral component of an article (as defined at 40 CFR 704.3) that is distributed for industrial, trade or consumer use. The use of perchloroethylene in plastic and rubber manufacturing and the use in textile processing (as a finishing agent) are the only uses that would incorporate perchloroethylene into an article. Perchloroethylene may also be used in the plastics and rubber product manufacturing as a degreasing solvent (NIOSH, 1994b). For descriptions of degreaser uses see Appendix B.1.3.2.

#### ***Plastics and Rubber Product Manufacturing***

In plastic manufacturing, the final plastic article is produced in a conversion process that forms the compounded plastic into the finished products (U.S. EPA, 2014c; OECD, 2009b). The converting process is different depending on whether the plastic is a thermoplastic or a thermosetting material (OECD, 2009b). Thermoplastics converting involves the melting of the plastic material, forming it into a new shape and then cooling it (U.S. EPA, 2014c; OECD, 2009b). The converting of thermoplastics may involve extrusion, injection molding, blow molding, rotational molding or thermoforming (U.S. EPA, 2014c; OECD, 2009b).

Conversion of thermosetting materials involves using heat and pressure to promote curing, typically through cross-linking (OECD, 2009b). The primary conversion process for thermosetting materials is compression molding; however, fiber reinforced thermosetting plastics are converted using hand layup, spray molding and filament winding (OECD, 2009b). After the forming process, finishing operations such as filing, grinding, sanding, polishing, painting, bonding, coating and engraving are performed to complete the process (U.S. EPA, 2014c).

### ***Textile Processing***

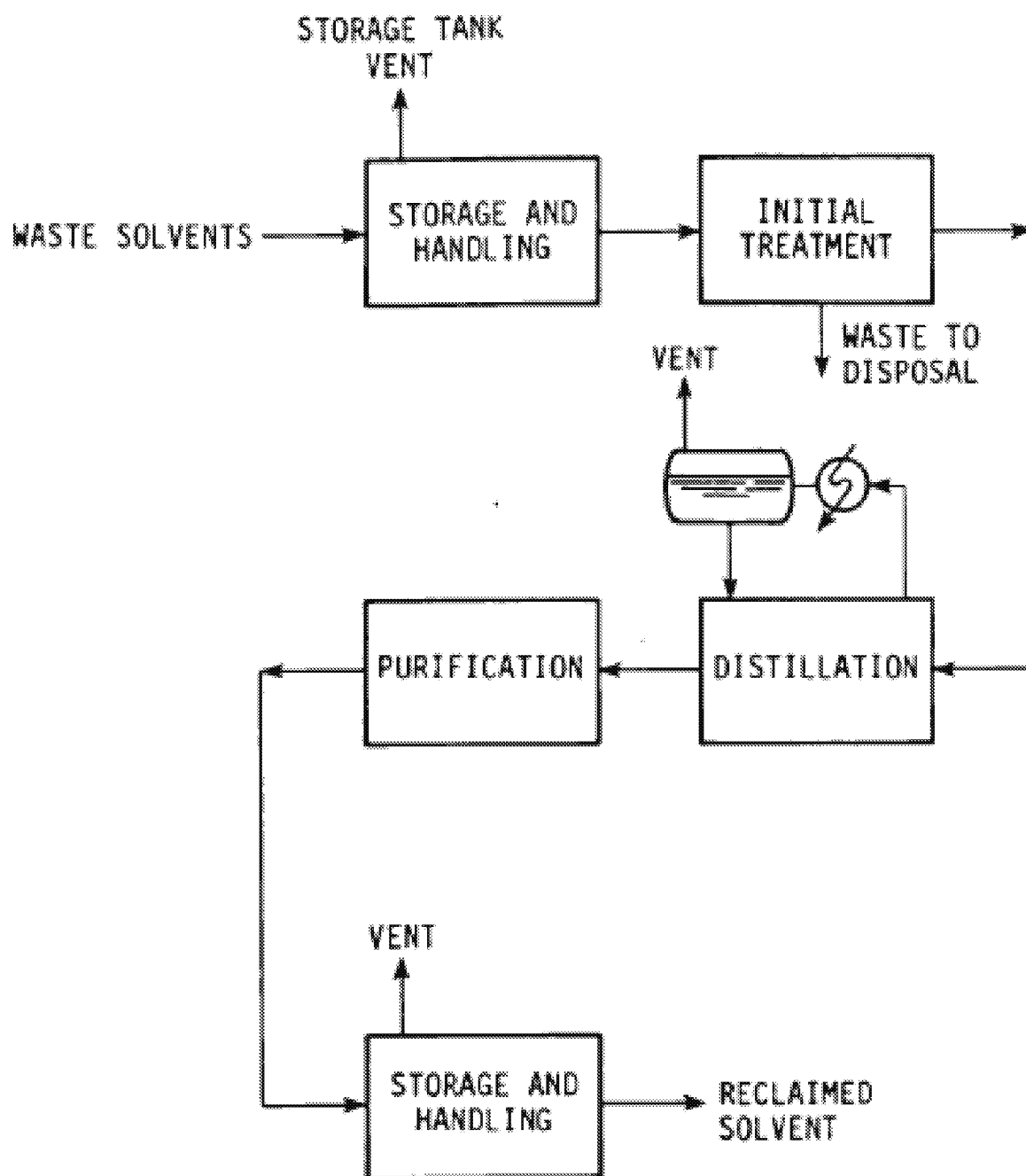
In textile processing, the purpose of the finishing stage is to impart special qualities to the textile (i.e. article). Perchloroethylene may be used as a water and stain repellant or as a fabric protector during textile finishing [cite market report]. Finishes may include mechanical treatments (e.g., calendaring and napping) or chemical treatments (e.g. stiffening, softening, water and soil repellents, antimicrobials, and fire retardants) (OECD, 2004b). The finishing process occurs after the textile is pre-treated and/or dyed/printed (OECD, 2004b). Chemical finishes are applied from aqueous solution/dispersions using the pad/dry/cure process (OECD, 2004b). In this process, the fabric is immersed in the aqueous finishing solution and then squeezed between metal rolls to remove excess solution and evenly distribute the finishing agent (OECD, 2004b). The fabric is then passed over a series of heated metal rolls for drying and cured using an oven (OECD, 2004b).

#### **B.1.2.4 Repackaging**

Typical repackaging sites receive the chemical in bulk containers and transfer the chemical from the bulk container into another smaller container in preparation for distribution in commerce.

#### **B.1.2.5 Recycling**

Waste perchloroethylene solvent is generated when it becomes contaminated with suspended and dissolved solids, organics, water or other substance (U.S. EPA, 1980c). Waste solvents can be restored to a condition that permits reuse via solvent reclamation/recycling (U.S. EPA, 1985a, 1980c). Waste perchloroethylene is shipped to a solvent recovery site where it is piped or manually loaded into process equipment (U.S. EPA, 1985a). The waste solvent then undergoes a vapor recovery (e.g., condensation, adsorption and absorption) or mechanical separation (e.g., decanting, filtering, draining, setline and centrifuging) step followed by distillation, purification and final packaging (U.S. EPA, 1985a, 1980c). Figure\_Apx B-4 illustrates a typical perchloroethylene solvent recovery process flow diagram (U.S. EPA, 1985a).



Figure\_Apx B-4. Process Flow Diagram of Perchloroethylene Solvent Recovery (U.S. EPA, 1985b)

### **B.1.3 Uses**

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In this document, EPA has grouped uses based on CDR categories, and identified examples within these categories as subcategories of use. Note that some subcategories of use may be grouped under multiple CDR categories. The differences between these uses will be further investigated and defined later during risk evaluation.

#### **B.1.3.1 Cleaning and Furniture Care Products**

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The “Cleaning and Furniture Care Products” category encompasses chemical substances contained in products that are used to remove dirt, grease, stains and foreign matter from furniture and furnishings or to cleanse, sanitize, bleach, scour, polish, protect or improve the appearance of surfaces. Products designed to clean wood floors or other substrates which contain perchloroethylene are used in industrial or commercial settings and are primarily formulated as liquids.

##### ***Dry Cleaning Solvent and Spot Cleaner***

Perchloroethylene can be used as a solvent in dry cleaning machines and is found in products used to spot clean garments. Spot cleaning products can be applied to the garment either before or after the garment is dry cleaned. The process and worker activities associated with commercial dry cleaning and spot cleaning have been previously described in EPA’s 1-Bromopropane (1-BP) Draft Risk Assessment ([U.S. EPA, 2016c](#)). Note: The 1-BP risk assessment focuses on use at commercial dry cleaning facilities; however, according to EPA’s *Economic Impact Analysis of the Final Perchloroethylene Dry Cleaning Residual Risk Standard* ([U.S. EPA, 2006a](#)), there are seven industrial dry cleaners that use perchloroethylene. Industrial dry cleaners clean heavily stained articles such as work gloves, uniforms, mechanics’ overalls, mops and shop rags ([U.S. EPA, 2006a](#)). The general worker activities at industrial dry cleaners are not expected to significantly differ from activities at commercial dry cleaners.

##### ***Non-Aerosol Degreasers and Cleaners***

Perchloroethylene can also be used as a solvent in non-aerosol degreasing and cleaning products. Non-aerosol cleaning products typically involve dabbing or soaking a rag with cleaning solution and then using the rag to wipe down surfaces or parts to remove contamination ([U.S. EPA, 2014a](#)). The cleaning solvent is usually applied in excess and allowed to air-dry ([U.S. EPA, 2014a](#)). Parts may be cleaned in place or removed from the service item for more thorough cleaning ([U.S. EPA, 2014a](#)).

##### ***Aerosol Spray Degreasers and Cleaners***

Aerosol degreasing is a process that uses an aerosolized solvent spray, typically applied from a pressurized can, to remove residual contaminants from fabricated parts. Products containing perchloroethylene may be used in aerosol degreasing applications such as brake cleaning, engine degreasing and metal product cleaning. This use has been previously described in EPA’s 1-BP Draft Risk Assessment ([U.S. EPA, 2016c](#)). Aerosol degreasing may occur at either industrial facilities or at commercial repair shops to remove contaminants on items being serviced. Aerosol degreasing products may also be purchased and used by consumers for various applications.

#### **B.1.3.2 Solvents for Cleaning and Degreasing**

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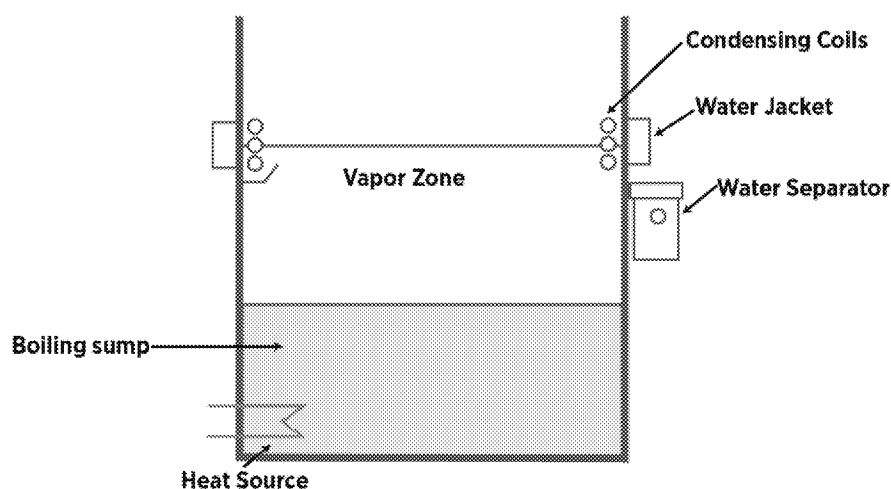
EPA has gathered information on different types of cleaning and degreasing systems from recent TCE risk assessment ([U.S. EPA, 2014e](#)) and risk management activities (FR 81(242): 91592-91624, December 16, 2016, and FR 82(12): 7432-7461, January 19, 2017) and 1-BP risk assessment ([U.S. EPA, 2016c](#)) activities. Provided below are descriptions of five cleaning and degreasing uses of perchloroethylene.

### ***Vapor Degreasers***

Vapor degreasing is a process used to remove dirt, grease and surface contaminants in a variety of metal cleaning industries. Vapor degreasing may take place in batches or as part of an in-line (i.e., continuous) system. Vapor degreasing equipment can generally be categorized into one of three degreaser types described below:

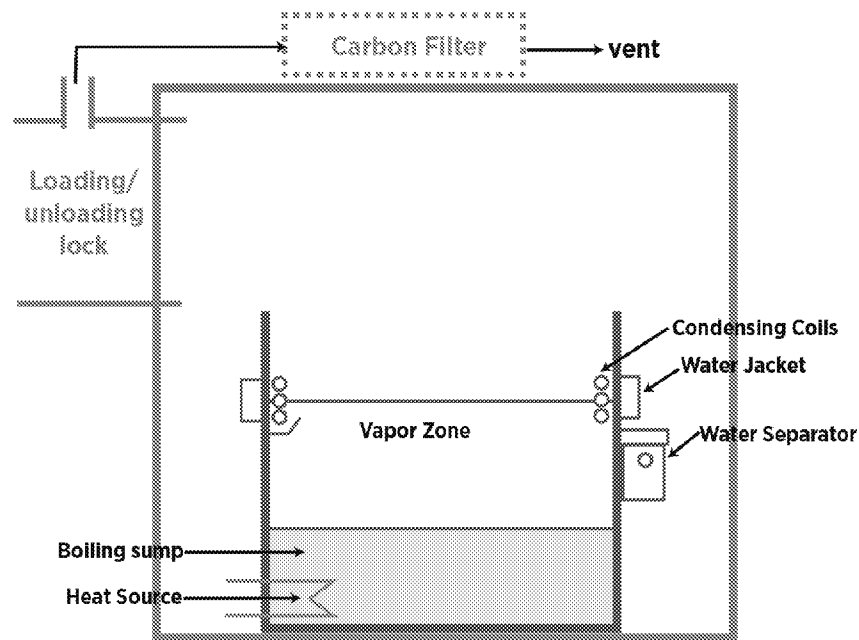
**Batch vapor degreasers:** In batch machines, each load (parts or baskets of parts) is loaded into the machine after the previous load is completed. Individual organizations, regulations and academic studies have classified batch vapor degreasers differently. For the purposes of the scope document, EPA categorizes the batch vapor degreasers into five types: open top vapor degreasers (OTVDs); OTVDs with enclosures; closed-loop degreasing systems (airtight); airless degreasing systems (vacuum drying); and airless vacuum-to-vacuum degreasing systems.

- Open top vapor degreasers (OTVD) – In OTVDs, a vapor cleaning zone is created by heating the liquid solvent in the OTVD causing it to volatilize. Workers manually load or unload fabricated parts directly into or out of the vapor cleaning zone. The tank usually has chillers along the side of the tank to prevent losses of the solvent to the air. However, these chillers are not able to eliminate emissions, and throughout the degreasing process significant air emissions of the solvent can occur. These air emissions can cause issues with both worker health and safety as well as environmental issues. Additionally, the cost of replacing solvent lost to emissions can be expensive (NEWMOA, 2001). Figure\_Apx B-5 illustrates a standard OTVD.



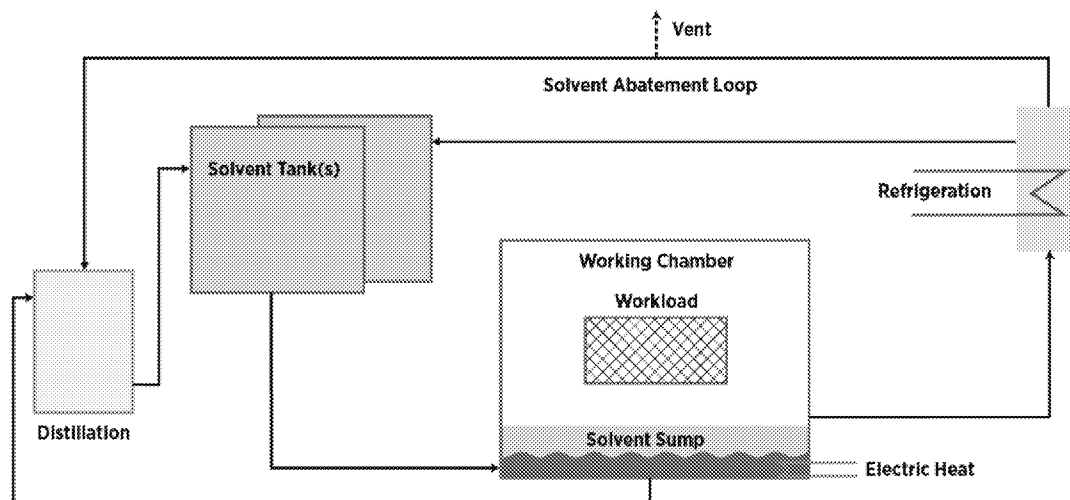
**Figure\_Apx B-5. Open Top Vapor Degreaser**

- OTVD with enclosure – OTVDs with enclosures operate the same as standard OTVDs except that the OTVD is enclosed on all sides during degreasing. The enclosure is opened and closed to add or remove parts to/from the machine, and solvent is exposed to the air when the cover is open. Enclosed OTVDs may be vented directly to the atmosphere or first vented to an external carbon filter and then to the atmosphere (U.S. EPA; ICF Consulting, 2004; U.S. EPA). Figure\_Apx B-6 illustrates an OTVD with an enclosure. The dotted lines in Figure\_Apx B-6 represent the optional carbon filter that may or may not be used with an enclosed OTVD.



**Figure\_Apx B-6. Open Top Vapor Degreaser with Enclosure**

- Closed-loop degreasing system (Airtight) – In closed-loop degreasers, parts are placed into a basket, which is then placed into an airtight work chamber. The door is closed and solvent vapors are sprayed onto the parts. Solvent can also be introduced to the parts as a liquid spray or liquid immersion. When cleaning is complete, vapors are exhausted from the chamber and circulated over a cooling coil where the vapors are condensed and recovered. The parts are dried by forced hot air. Air is circulated through the chamber and residual solvent vapors are captured by carbon adsorption. The door is opened when the residual solvent vapor concentration has reached a specified level (Kanegsberg and Kanegsberg, 2011). Figure\_Apx B-7 illustrates a standard closed-loop vapor degreasing system.



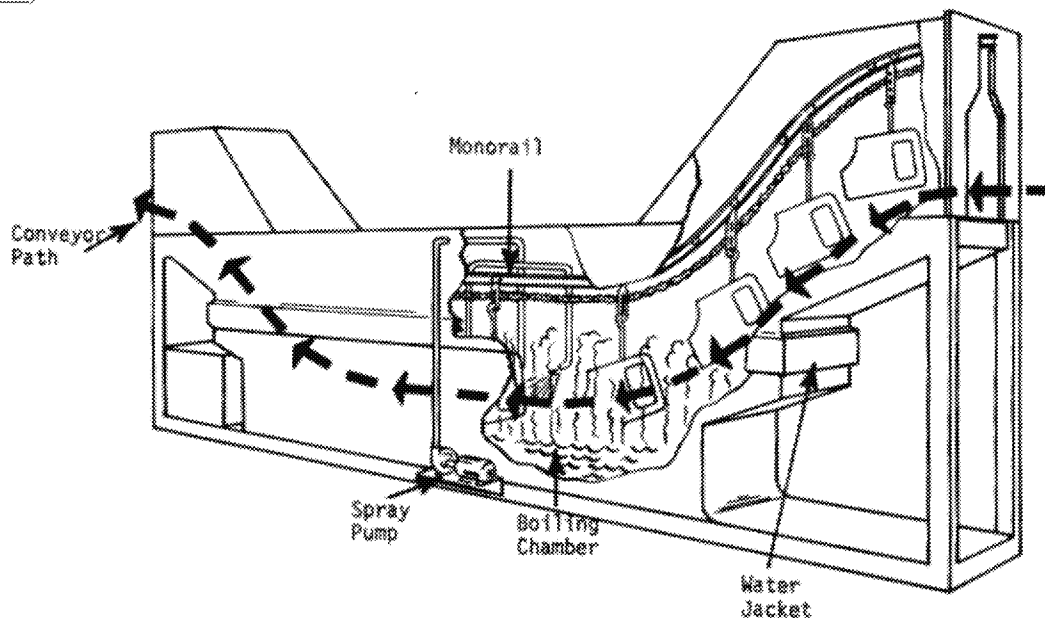
**Figure\_Apx B-7. Closed-loop/Vacuum Vapor Degreaser**

- Airless degreasing system (vacuum drying) – Airless degreasing systems are also sealed, closed-loop systems, but remove air at some point of the degreasing process. Removing air typically takes the form of drawing vacuum, but could also include purging air with nitrogen at some point of the process (in contrast to drawing vacuum, a nitrogen purge operates at a slightly positive pressure). In airless degreasing systems with vacuum drying only, the cleaning stage works similarly as with the airtight closed-loop degreaser. However, a vacuum is generated during the drying stage, typically below 5 torr (5 mmHg). The vacuum dries the parts and a vapor recovery system captures the vapors (Kanegsberg and Kanegsberg, 2011; NEWMOA, 2001; U.S. EPA, 2001a).
- Airless vacuum-to-vacuum degreasing system – Airless vacuum-to-vacuum degreasers are true “airless” systems because the entire cycle is operated under vacuum. Typically, parts are placed into the chamber, the chamber sealed, and then vacuum drawn within the chamber. The typical solvent cleaning process is a hot solvent vapor spray. The introduction of vapors in the vacuum chamber raises the pressure in the chamber. The parts are dried by again drawing vacuum in the chamber. Solvent vapors are recovered through compression and cooling. An air purge then purges residual vapors over an optional carbon adsorber and through a vent. Air is then introduced in the chamber to return the chamber to atmospheric pressure before the chamber is opened (Durkee, 2014; NEWMOA, 2001).

The general design of vacuum vapor degreasers and airless vacuum degreasers is similar as illustrated in Figure\_Apx B-7 for closed-loop systems except that the work chamber is under vacuum during various stages of the cleaning process.

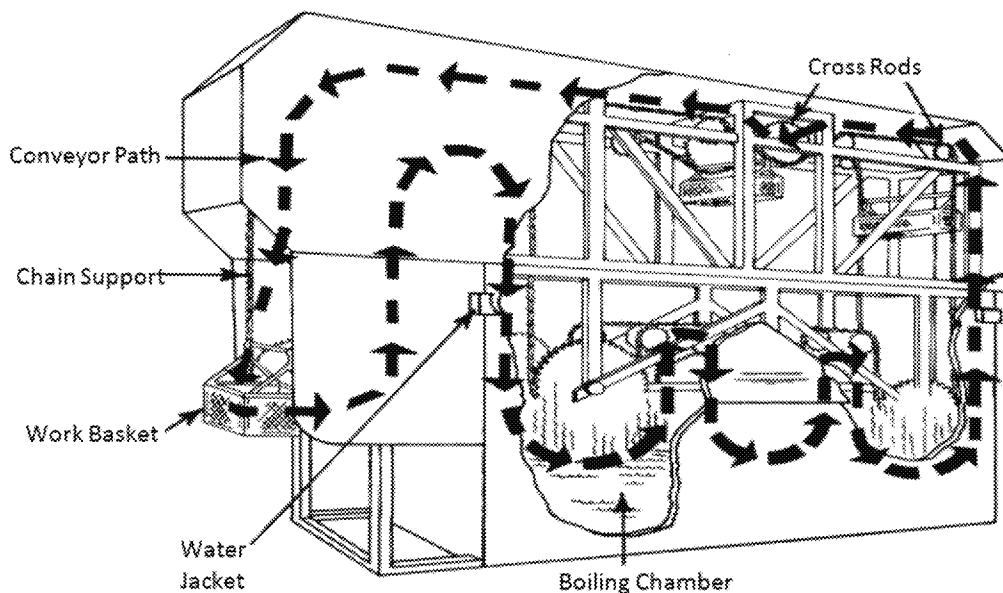
**Conveyorized vapor degreasers:** In conveyorized systems, an automated parts handling system, typically a conveyor, continuously loads parts into and through the vapor degreasing equipment and the subsequent drying steps. Conveyorized degreasing systems are usually fully enclosed except for the conveyor inlet and outlet portals. Conveyorized degreasers are likely used in shops where there are a large number of parts being cleaned. There are seven major types of conveyorized degreasers: monorail degreasers; cross-rod degreasers; vibra degreasers; ferris wheel degreasers; belt degreasers; strip degreasers; and circuit board degreasers (U.S. EPA, 1977).

- Monorail Degreasers – Monorail degreasing systems are typically used when parts are already being transported throughout the manufacturing areas by a conveyor (U.S. EPA, 1976). They use a straight-line conveyor to transport parts into and out of the cleaning zone. The parts may enter one side and exit on the other or may make a 180° turn and exit through a tunnel parallel to the entrance (U.S. EPA, 1976). Figure\_Apx B-8 illustrates a typical monorail degreaser (U.S. EPA, 1976).



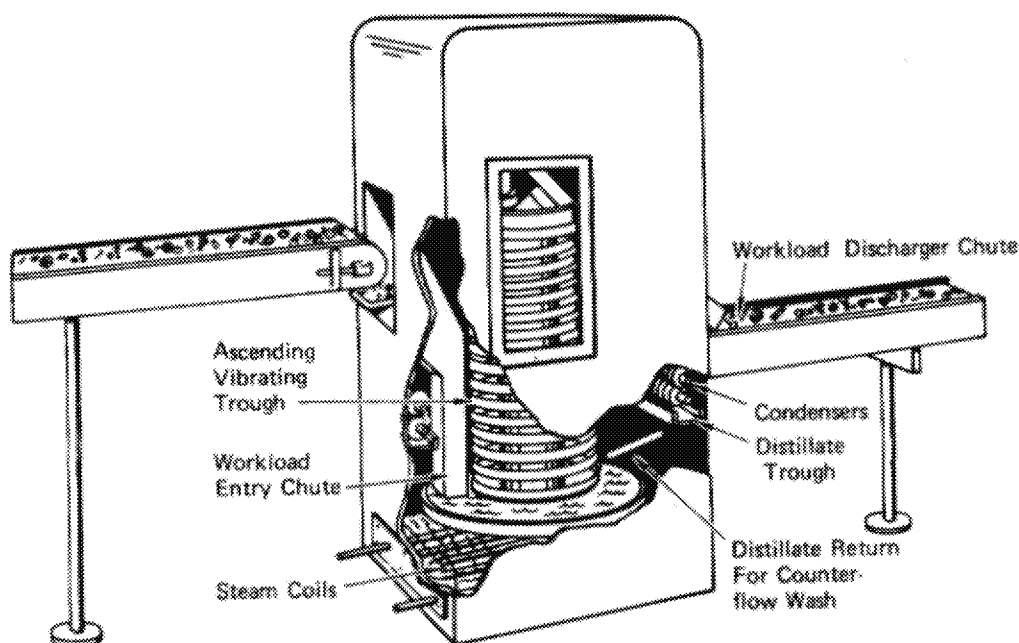
**Figure\_Apx B-8. Monorail ConveyORIZED Vapor Degreasing System (EPA, 1977a)**

- Cross-rod Degreasers – Cross-rod degreasing systems utilize two parallel chains connected by a rod that support the parts throughout the cleaning process. The parts are usually loaded into perforated baskets or cylinders and then transported through the machine by the chain support system. The baskets and cylinders are typically manually loaded and unloaded (U.S. EPA, 1976). Cylinders are used for small parts or parts that need enhanced solvent drainage because of crevices and cavities. The cylinders allow the parts to be tumbled during cleaning and drying and thus increase cleaning and drying efficiency. Figure\_Apx B-9 illustrates a typical cross-rod degreaser (U.S. EPA, 1976).



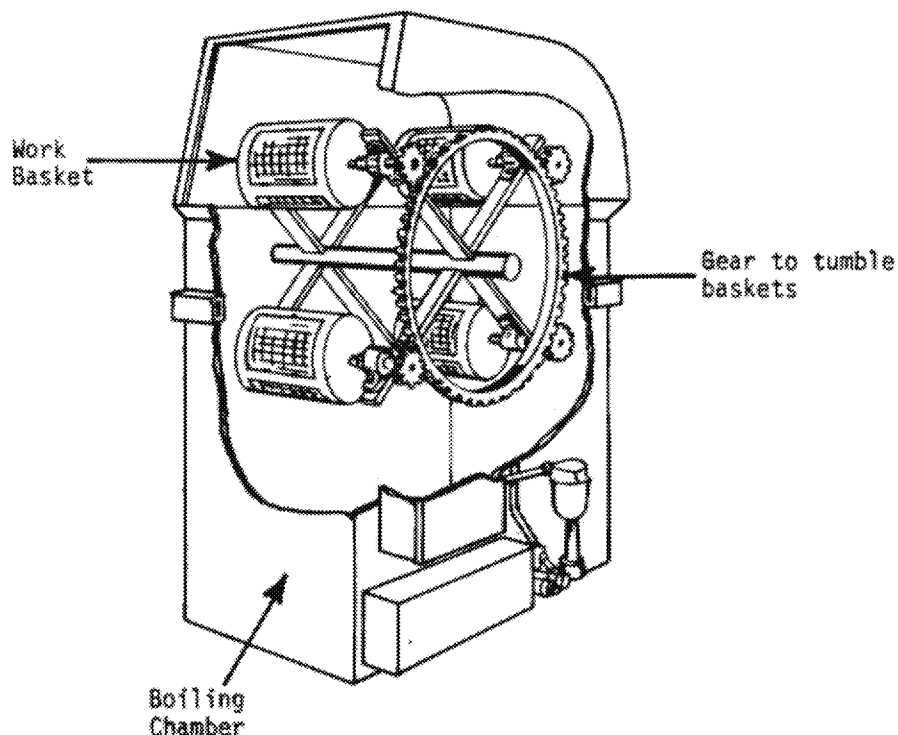
**Figure\_Apx B-9. Cross-Rod Conveyorized Vapor Degreasing System (EPA, 1977a)**

- Vibra Degreasers – In vibra degreasing systems, parts are fed by conveyor through a chute that leads to a pan flooded with solvent in the cleaning zone. The pan and the connected spiral elevator are continuously vibrated throughout the process causing the parts to move from the pan and up a spiral elevator to the exit chute. As the parts travel up the elevator, the solvent condenses and the parts are dried before exiting the machine (U.S. EPA, 1976). Figure\_Apx B-10 illustrates a typical vibra degreaser (U.S. EPA, 1976).



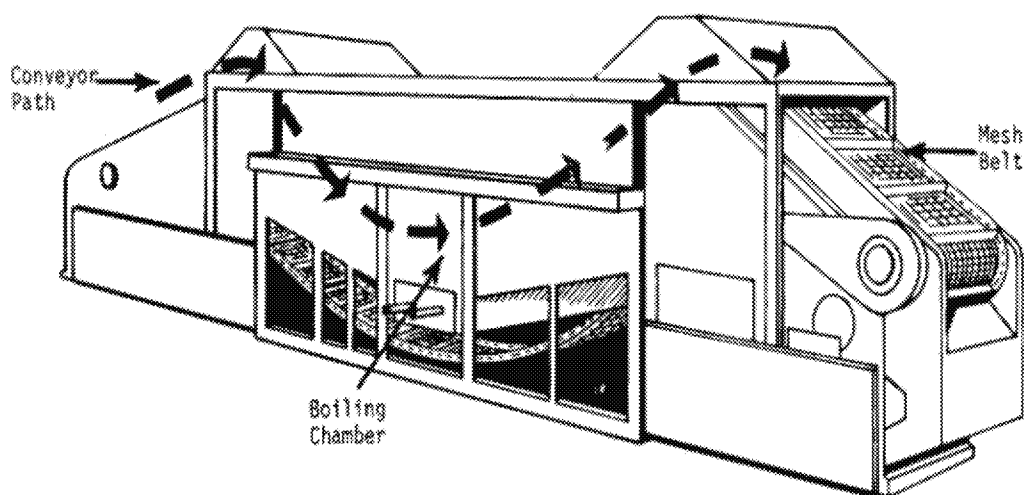
**Figure\_Apx B-10. Vibra Conveyorized Vapor Degreasing System (U.S. EPA, 1977)**

- Ferris wheel degreasers – Ferris wheel degreasing systems are generally the smallest of all the conveyORIZED degreasers (U.S. EPA, 1976). In these systems, parts are manually loaded into perforated baskets or cylinders and then rotated vertically through the cleaning zone and back out. Figure\_Apx B-11 illustrates a typical ferris wheel degreaser (U.S. EPA, 1976).



**Figure\_Apx B-11. Ferris Wheel ConveyORIZED Vapor Degreasing System (EPA, 1977a)**

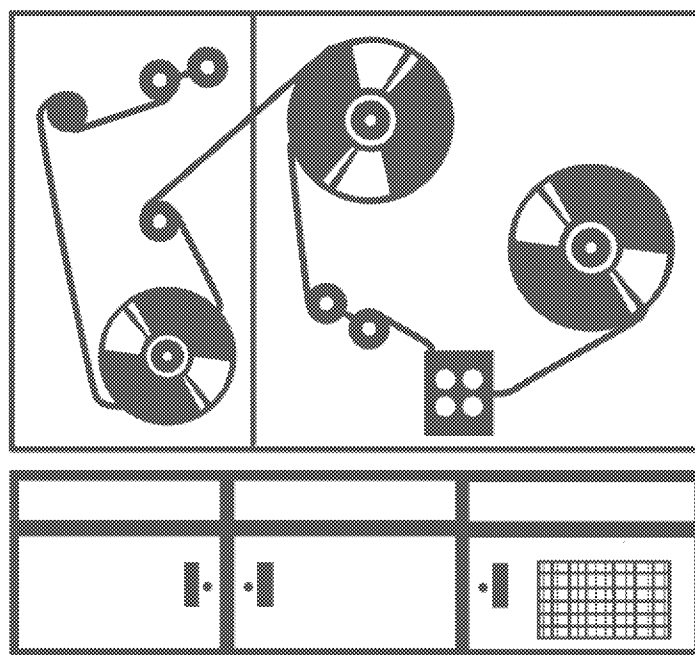
- Belt degreasers – Belt degreasing systems (similar to strip degreasers; see next bullet) are used when simple and rapid loading and unloading of parts is desired (U.S. EPA, 1976). Parts are loaded onto a mesh conveyor belt that transports them through the cleaning zone and out the other side. Figure\_Apx B-12 illustrates a typical belt or strip degreaser (U.S. EPA, 1976).



**Figure\_Apx B-12. Belt/Strip ConveyORIZED Vapor Degreasing System (U.S. EPA, 1977)**

- Strip degreasers – Strip degreasing systems operate similar to belt degreasers except that the belt itself is being cleaned rather than parts being loaded onto the belt for cleaning. Figure\_Apx B-12 illustrates a typical belt or strip degreaser (U.S. EPA, 1976).
- Circuit board cleaners – Circuit board degreasers use any of the conveyORIZED designs. However, in circuit board degreasing, parts are cleaned in three different steps due to the manufacturing processes involved in circuit board production (U.S. EPA, 1976).

**Continuous web vapor degreasers:** Continuous web cleaning machines are a subset of conveyORIZED degreasers but differ in that they are specifically designed for cleaning parts that are coiled or on spools such as films, wires and metal strips (Kanegsberg and Kanegsberg, 2011; U.S. EPA, 2006b). In continuous web degreasers, parts are uncoiled and loaded onto rollers that transport the parts through the cleaning and drying zones at speeds greater than 11 feet per minute (U.S. EPA, 2006b). The parts are then recoiled or cut after exiting the cleaning machine (Kanegsberg and Kanegsberg, 2011; U.S. EPA, 2006b). Figure\_Apx B-13 illustrates a typical continuous web cleaning machine.



**Figure\_Apx B-13. Continuous Web Vapor Degreasing System**

### ***Cold Cleaners***

Perchloroethylene can also be used as a solvent in cold cleaners, which are non-boiling solvent degreasing units. Cold cleaning operations include spraying, brushing, flushing and immersion. In a typical batch-loaded, maintenance cold cleaner, dirty parts are cleaned manually by spraying and then soaking in the tank. After cleaning, the parts are either suspended over the tank to drain or are placed on an external rack that routes the drained solvent back into the cleaner. Batch manufacturing cold cleaners could vary widely, but have two basic equipment designs: the simple spray sink and the dip tank. The dip tank design typically provides better cleaning through immersion, and often involves an immersion tank equipped with agitation (U.S. EPA, 1981). Emissions from batch cold cleaning machines typically result from (1) evaporation of the solvent from the solvent-to-air interface, (2) “carry out” of excess solvent on cleaned parts and (3) evaporative losses of the solvent during filling and draining of the machine (U.S. EPA, 2006b).

### ***Non-Aerosol Degreasers and Cleaners***

Perchloroethylene can also be used as a solvent in non-aerosol degreasing and cleaning products. Non-aerosol cleaning products typically involve dabbing or soaking a rag with cleaning solution and then using the rag to wipe down surfaces or parts to remove contamination ([U.S. EPA, 2014a](#)). The cleaning solvent is usually applied in excess and allowed to air-dry ([U.S. EPA, 2014a](#)). Parts may be cleaned in place or removed from the service item for more thorough cleaning ([U.S. EPA, 2014a](#)).

### ***Aerosol Spray Degreasers and Cleaners***

Aerosol degreasing is a process that uses an aerosolized solvent spray, typically applied from a pressurized can, to remove residual contaminants from fabricated parts. Products containing perchloroethylene may be used in aerosol degreasing applications such as brake cleaning, engine degreasing and metal product cleaning. This use has been previously described in EPA's 1-BP Draft Risk Assessment([U.S. EPA, 2016c](#)). Aerosol degreasing may occur at either industrial facilities or at commercial repair shops to remove contaminants on items being serviced. Aerosol degreasing products may also be purchased and used by consumers for various applications.

#### **B.1.3.3 Lubricant and Greases**

In the 2016 CDR ([U.S. EPA, 2016b](#)), two companies reported commercial use of perchloroethylene in lubricants and greases. The *Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal: Tetrachloroethylene (Perchloroethylene)* [[EPA-HQ-OPPT-2016-0732-0003](#) ] identified perchloroethylene in penetrating lubricants, cutting oils, aerosol lubricants, red greases, white lithium greases, silicone lubricants and greases and chain and cable lubricants. Most of the products identified by EPA are applied by either aerosol or non-aerosol spray applications.

#### **B.1.3.4 Adhesives and Sealants**

Based on products identified in *Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal: Tetrachloroethylene (Perchloroethylene)* [[EPA-HQ-OPPT-2016-0732-0003](#) ] and 2016 CDR reporting, perchloroethylene may be used in adhesive and sealants for industrial, commercial and consumer applications ([U.S. EPA, 2016b](#)). The OECD ESD for Use of Adhesives ([OECD, 2013](#)) provides general process descriptions and worker activities for industrial adhesive uses.

Liquid adhesives are unloaded from containers into the coating reservoir, applied to a flat or three-dimensional substrate and the substrates are then joined and allowed to cure ([OECD, 2013](#)). The majority of adhesive applications include spray, roll, curtain, syringe or bead application ([OECD, 2013](#)). For solvent-based adhesives, the volatile solvent (in this case perchloroethylene) evaporates during the curing stage ([OECD, 2013](#)). Worker activities include unloading activities, container and equipment cleaning activities and manual applications of adhesive ([OECD, 2013](#)). Based on EPA's knowledge of the industry, overlap in process descriptions, worker activities and application methods are expected for sealant products.

EPA's *Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal: Tetrachloroethylene (Perchloroethylene)* ([EPA-HQ-OPPT-2016-0732-0003](#)) states that the use of perchloroethylene in consumer adhesives is especially prevalent with uses in arts and crafts and light repairs. EPA has also identified several sealants and adhesives that contain perchloroethylene and are marketed for commercial uses, such as construction applications. Based on EPA's knowledge of the industry, the likely application methods for commercial and consumer uses include spray, brush, syringe, eyedropper, roller and bead applications.

#### **B.1.3.5 Paints and Coatings**

Based on products identified in *Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal: Tetrachloroethylene (Perchloroethylene)* (EPA-HQ-OPPT-2016-0732-0003) ] and 2016 CDR reporting (U.S. EPA, 2016b), perchloroethylene may be used in various paints and coatings for industrial, commercial and consumer applications. Several OECD ESDs and EPA generic scenarios provide general process descriptions and worker activities for industrial and commercial uses.

Typical coating applications include manual application with roller or brush, air spray systems, airless and air-assisted airless spray systems, electrostatic spray systems, electrodeposition/electrocoating and autodeposition, dip coating, curtain coating systems, roll coating systems and supercritical carbon dioxide systems (OECD, 2009c). After application, solvent-based coatings typically undergo a drying stage in which the solvent evaporates from the coating (OECD, 2009c).

#### **B.1.3.6 Processing Aid for Pesticide, Fertilizer and Other Agricultural Manufacturing**

In the 2016 CDR (U.S. EPA, 2016b), two sites owned by Olin Corporation reported use of perchloroethylene as a “processing aid, not otherwise listed” for use in the “pesticide, fertilizer, and other agricultural chemical manufacturing” industry.

#### **B.1.3.7 Processing Aid, Specific to Petroleum Production**

In the 2016 CDR (U.S. EPA, 2016b), two sites owned by Olin Corporation reported use of perchloroethylene as a “processing aid, specific to petroleum production” for use in the “Petrochemical Manufacturing” industry. A Dow Product Safety Assessment (Dow Chemical Co, 2008) for perchloroethylene describes a use at oil refineries for catalyst regeneration. However, a public comment from AFPM (Public Comment, EPA-HQ-OPPT-2016-0732-0018) indicates that perchloroethylene is consumed in the catalyst regeneration process and therefore would be considered an “intermediate” (see Appendix B.1.2.1 for description). It is unclear if this CDR reporting code is related to the use in catalyst regeneration or another processing aid use.

#### **B.1.3.8 Other Uses**

##### ***Other Industrial Uses***

Based on products identified in *Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal: Tetrachloroethylene (Perchloroethylene)* (EPA-HQ-OPPT-2016-0732-0003) , a variety of other industrial uses may exist for perchloroethylene, including textile processing, laboratory applications, foundry applications and wood furniture manufacturing. It is unclear at this time the total volume of perchloroethylene used in any of these applications. More information on these uses will be gathered through expanded literature searches in subsequent phases of the risk evaluation process.

##### ***Other Commercial/Consumer Uses***

Based on products identified in EPA’s *Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal: Tetrachloroethylene (Perchloroethylene)* (EPA-HQ-OPPT-2016-0732-0003) , a variety of other commercial and consumer uses may exist for perchloroethylene including carpet cleaning; laboratory applications; metal and stone polishes; inks and ink removal products; welding applications; photographic film applications; mold cleaning, release and protectant products. Similar to the “Other” industrial uses, more information on these uses will be gathered through expanded literature searches in subsequent phases of the risk evaluation process.

#### **B.1.4 Disposal**

Perchloroethylene is listed as a hazardous waste under RCRA and federal regulations prevent land disposal of various chlorinated solvents that may contain perchloroethylene (ATSDR, 2014).

Perchloroethylene may be disposed of by absorption in vermiculite, dry sand, earth or other similar material and then buried in a secured sanitary landfill or incineration ([HSDB, 2012](#)). In incineration, complete combustion is necessary to prevent phosgene formation and acid scrubbers must be used to remove any haloacids produced ([ATSDR, 2014](#)). Perchloroethylene may also be discharged to waterways if proper permits are held ([ATSDR, 2014](#)).

## **B.2 Occupational Exposure Data**

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EPA presents below an example of occupational exposure-related information from the preliminary data gathering. EPA will consider this information and data in combination with other data and methods for use in the risk evaluation.

Table\_Apx B-1 summarizes personal monitoring OSHA CEHD data by NAICS code ([OSHA, 2017a](#)) and Table\_Apx B-2 summarizes NIOSH HHE data.

**Table\_Apx B-1. Summary of Perchloroethylene Personal Monitoring Air Samples Obtained from OSHA Inspections Conducted Between 2011 and 2016**

Release/Exposure Scenario	NAICS	NAICS Description	8-hr TWA Concentration (ppm) <sup>a</sup>					STEL, Peak, or Ceiling Concentration (ppm)				
			Number of Data Points	Minimum	Maximum	Average	Number of Zero Values <sup>b</sup>	Number of Data Points	Minimum	Maximum	Average	Number of Zero Values <sup>b</sup>
Unknown, company inspected is an excavation contractor, possibly from contact with soil contaminated with perchloroethylene	236220	Commercial and Institutional Building Construction	2	0	0	0	2		0	0	0	2
Unknown, likely impurity in refrigerant	238220	Plumbing, Heating, and Air-Conditioning Contractors	1	5.2			0	No Data Available				
Textile pre-treatment or textile finishing	313310	Textile and Fabric Finishing Mills	1		0		1	1		0		1
Textile pre-treatment or textile finishing	313312	Textile and Fabric Finishing (except Broadwoven Fabric) Mills <sup>c</sup>	1		0		1	1		0		1
Other uses (ink and ink removal products), wipe cleaning, or aerosol degreasing	323113	Commercial Screen Printing	1		0		1	1		0		1
Plastics converting (possibly as a degreaser/cleaner, mold release agent, or paint/coating)	326199	All Other Plastics Product Manufacturing	2	0.2	0.3	0.2	0	1		0.9		0
Vapor degreasing or cold cleaning	331512	Steel Investment Foundries	3	0.02	0.03	0.02	0	No Data Available				
Vapor degreasing or cold cleaning	332439	Other Metal Container Manufacturing	2	0.03	0.03	0.03	0	No Data Available				
Vapor degreasing or cold cleaning	332991	Ball and Roller Bearing Manufacturing	3	0	0	0	3	3	0	0	0	3
Vapor degreasing or cold cleaning	332996	Fabricated Pipe and Pipe Fitting Manufacturing	3	0	0	0	3	3	0	0	0	3

Release/Exposure Scenario	NAICS	NAICS Description	8-hr TWA Concentration (ppm) <sup>a</sup>				STEL, Peak, or Ceiling Concentration (ppm)					
			Number of Data Points	Minimum	Maximum	Ave rage	Number of Zero Values <sup>b</sup>	Number of Data Points	Minimum	Maximum	Ave rage	Number of Zero Values <sup>b</sup>
Vapor degreasing or cold cleaning	334511	Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing	1		0.3		0	1		0.3		0
Vapor degreasing or cold cleaning	335999	All Other Miscellaneous Electrical Equipment and Component Manufacturing	1		2.1		0	1		19		0
Unknown, likely impurity in refrigerant	445110	Supermarkets and Other Grocery (except Convenience) Stores	2	0	0	0	2	2	0	0	0	2
Industrial and commercial dry cleaning	448110	Men's Clothing Stores	1		7.8		0	1		8.6		0
Commercial auto repair/servicing	485410	School and Employee Bus Transportation	1		63		0	1		100		0
Commercial auto repair/servicing	811198	All Other Automotive Repair and Maintenance	1		110		0	1		120		0
Industrial and commercial dry cleaning	812310	Coin-Operated Laundries and Drycleaners	1		2.3		0	1		9.1		0
Industrial and commercial dry cleaning	812320	Drycleaning and Laundry Services (except Coin-Operated)	30	0.1	390	27.8	0	22	0.5	480	55.4	0
Unknown – this seems to be for OSHA inspectors which could have been collected during site inspections	926150	Regulation, Licensing, and Inspection of Miscellaneous Commercial Sectors	6	0	7.2	1.4	3	6	0	7.2	1.6	3
Vapor degreasing, cold cleaning, aerosol degreasing, wipe cleaning or other uses (laboratory chemical)	927110	Space Research and Technology	1		0		1	1		0		1

<sup>a</sup> Assumes all TWA data are 8-hr TWA.

<sup>b</sup> For facilities where all samples are measured as zero, it is unclear if perchloroethylene is present at the facility. For facilities where the samples are zero and other samples are greater than zero, the zero values likely represent non-detects.

<sup>c</sup> This is a 2007 NAICS code, the corresponding 2012 and 2017 NAICS code is 313310 for "Textile and Fabric Finishing Mills."

Note: The data set also includes samples for a facility classified using the 2012/2017 NAICS code as a separate line item. All data for both NAICS codes were zero values.

**Table\_Apx B-2. Summary of Monitoring Data from NIOSH Health Hazard Evaluations Conducted since 1990**

Data Source	Report Number	Exposure/Release Scenario	Facility Description	Number of Exposure Samples	Minimum of Exposure Values (ppm)	Maximum of Exposure Values (ppm)	Comments
NIOSH, 1992	HETA 91-351-2252	Industrial and commercial dry cleaning	Office co-located with a dry cleaner	0	No exposure data provided.		
NIOSH, 1994	HETA 91-377-2383	Plastics converting (as a degreaser)	Molded rubber parts manufacturer	PBZ: 15 Area: 2	PBZ: ND Area: 0.76	PBZ: 5.3 Area: 1.2	PBZ: Full-shift TWA Area: 2-hr Measurement
NIOSH, 1999	HETA 98-0249-2773	Industrial and commercial dry cleaning	Dry cleaning facility in a hotel	PBZ: 5 Area: 2	PBZ: 0.17 Area: 5.6	PBZ: 5.8 Area: 7.4	All full-shift measurements. Study also took "real-time" peak measurements ranging from 377 to >2,000 ppm.
NIOSH, 2008	HETA 07-0055-3073	Commercial auto repair/ servicing	School bus maintenance shop	0	No exposure data provided.		

ND – Non-detect

## B.3 References related to Risk Evaluation – Environmental Release and Occupational Exposure

**Table\_Apx B-3. Potentially Relevant Data Sources for Process Description Related Information for Perchloroethylene<sup>3</sup>**

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**Table\_Apx B-4. Potentially Relevant Data Sources for Estimated or Measured Release Data for Perchloroethylene<sup>4</sup>**

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Empe, Inc Consulting Engineers (1986). Hazardous waste management study: Dry cleaners #journal#, #volume#(#issue#), #Pages#	EMPE (1986)
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**Table\_Apx B-5. Potentially Relevant Data Sources for Personal Exposure Monitoring and Area Monitoring Data for Perchloroethylene<sup>5</sup>**

Bibliography	url
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<sup>5</sup> The data sources identified are based on preliminary results to date of the full-text screening step of the Systematic Review process. Further screening and quality control are on-going.

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**Table\_Apx B-6. Potentially Relevant Data Sources for Engineering Controls and Personal Protective Equipment Information for Perchloroethylene<sup>6</sup>**

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<sup>6</sup> The data sources identified are based on preliminary results to date of the full-text screening step of the Systematic Review process. Further screening and quality control are on-going.

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## Appendix C SUPPORTING TABLE FOR INDUSTRIAL AND COMMERCIAL ACTIVITIES AND USES CONCEPTUAL MODEL

Table\_Apx C-1. Industrial and Commercial Activities and Uses Conceptual Model Supporting Table

Life Cycle Stage	Category	Subcategory	Release / Exposure Scenario	Exposure Pathway	Exposure Route	Receptor / Population	Proposed for Further Risk Evaluation	Rationale for Further Evaluation / no Further Evaluation
Manufacture	Domestic Manufacture	Domestic Manufacture	Manufacture of perchloroethylene via chlorination of ethylene dichloride, chlorination of C1-C3 hydrocarbons, oxychlorination of C2 chlorinated hydrocarbons, and as a byproduct	Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. Number of exposed workers may be high per CDR (2 submissions reported 100-500 workers each).
				Vapor	Inhalation	Workers	Yes	perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Mist	Dermal/Inhalation	Workers, ONU	No	Mist generation not expected during manufacturing.
Manufacture	Import	Import	Repackaging of import containers	Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. Exposure will only occur in the event the imported material is repackaged.
				Vapor	Inhalation	Workers	Yes	Exposure expected only in the event the imported material is repackaged into different sized containers. Exposure frequency may be low.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.

Life Cycle Stage	Category	Subcategory	Release / Exposure Scenario	Exposure Pathway	Exposure Route	Receptor / Population	Proposed for Further Risk Evaluation	Rationale for Further Evaluation / no Further Evaluation
Processing	Processing as a reactant	Intermediate in industrial gas manufacturing; all other basic inorganic chemical manufacturing; all other basic organic chemical manufacturing; and petroleum refining	Manufacture of HFCs, HFCs, CFCs, trichloroacetyl chloride, HCl, muriatic acid, and refinery reformer and isomerization catalyst regeneration	Vapor	Inhalation	ONU	Yes	Exposure expected only in the event the imported material is repackaged into different sized containers. Exposure frequency may be low.
				Mist	Dermal/ Inhalation	Workers, ONU	No	Mist generation not expected during import.
				Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. However, the number of workers may be high per CDR (1 submission reporting 10-25 workers, 2 submissions reporting 100-500 workers, and 5 submissions reporting NKRA).
				Vapor	Inhalation	Workers	Yes	perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed. However, potential for exposure may be low in scenarios where perchloroethylene is consumed as a chemical intermediate.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed. However, potential for exposure may be low in scenarios where perchloroethylene is consumed as a chemical intermediate.
				Mist	Dermal/ Inhalation	Workers, ONU	No	Mist generation not expected during processing as an intermediate.

Life Cycle Stage	Category	Subcategory	Release / Exposure Scenario	Exposure Pathway	Exposure Route	Receptor / Population	Proposed for Further Risk Evaluation	Rationale for Further Evaluation / no Further Evaluation
Processing	Incorporated into formulation, mixture or reaction product	Solvent for cleaning or degreasing; adhesive and sealant chemicals; paint and coating products; and other chemical products and preparations	Formulation of aerosol and non-aerosol products	Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. However, the number of workers may be high per CDR (1 submission reporting <10 workers, 1 submission reporting 10-25 workers, 1 submission reporting 25-50 workers, 2 submissions reporting 50-100 workers, 2 submissions reporting 100-500 workers, and 3 submissions reporting NKRA).
				Vapor	Inhalation	Workers	Yes	Inhalation exposure is expected at processing sites that formulate products containing perchloroethylene.
				Liquid Contact	Dermal	ONU	No	perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Vapor	Inhalation	ONU	Yes	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
Processing	Incorporated into articles	Plastics and rubber products manufacturing; and textile processing	Plastics converting; and textile finishing	Mist	Dermal/ Inhalation	Workers, ONU	No	Inhalation exposure is expected at processing sites that formulate products containing perchloroethylene.
				Liquid Contact	Dermal	Workers	Yes	perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Vapor	Inhalation	Workers	Yes	Mist generation not expected during processing/formulation operations.

Life Cycle Stage	Category	Subcategory	Release / Exposure Scenario	Exposure Pathway	Exposure Route	Receptor / Population	Proposed for Further Risk Evaluation	Rationale for Further Evaluation / no Further Evaluation
Processing	Repackaging	Solvent for cleaning or degreasing; and intermediate	Repackaging into large and small containers	Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	Inhalation exposure is expected at processing sites that incorporate perchloroethylene into articles. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Mist	Dermal/ Inhalation	Workers, ONU	No	Mist generation not expected during processing operations.
				Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. Exposure frequency may be low.
				Vapor	Inhalation	Workers	Yes	Exposure frequency may be low.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	Exposure frequency may be low.
				Mist	Dermal/ Inhalation	Workers, ONU	No	Mist generation not expected during repackaging.
Processing	Recycling	Recycling	Recycling of process solvents containing perchloroethylene	Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. EPA expects significant volume of perchloroethylene to be sent to off-site recycling (~67% of reported releases/transfers in TRI were reported as transfers to off-site recycling).
				Vapor	Inhalation	Workers	Yes	Inhalation exposure is expected at recycling sites. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed. EPA expects significant volume of perchloroethylene to be sent to off-site recycling (~67% of reported releases/transfers in TRI were reported as transfers to off-site recycling).

Life Cycle Stage	Category	Subcategory	Release / Exposure Scenario	Exposure Pathway	Exposure Route	Receptor / Population	Proposed for Further Risk Evaluation	Rationale for Further Evaluation / no Further Evaluation
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	Inhalation exposure is expected at recycling sites. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed. EPA expects significant volume of perchloroethylene to be sent to off-site recycling (~67% of reported releases/transfers in TRI were reported as transfers to off-site recycling).
				Mist	Dermal/ Inhalation	Workers, ONU	No	Mist generation not expected during recycling.
	Distribution in commerce	Distribution	Distribution of bulk shipment of perchloroethylene; and distribution of formulated products	Liquid Contact, Vapor	Dermal/ Inhalation	Workers, ONU	No	Exposure will only occur in the event of spills.

Life Cycle Stage	Category	Subcategory	Release / Exposure Scenario	Exposure Pathway	Exposure Route	Receptor / Population	Proposed for Further Risk Evaluation	Rationale for Further Evaluation / no Further Evaluation
Industrial use	Solvents (for cleaning or degreasing)	Batch vapor degreaser (e.g., open-top, closed-loop); and In-line vapor degreaser (e.g., conveyORIZED, web cleaner)	Open top vapor degreasing (OTVD); OTVD with enclosures; ConveyORIZED vapor degreasing; Cross-rod and ferris wheel vapor degreasing; Web vapor degreasing; Airtight closed-loop degreasing system; Airless vacuum-to-vacuum degreasing system; Airless vacuum drying degreasing system	Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. However, repeat contact or dermal immersion may occur, especially while cleaning and maintaining degreasing equipment.
				Vapor	Inhalation	Workers	Yes	Inhalation exposure is expected for vapor degreasing activities. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	Inhalation exposure is expected for vapor degreasing activities, perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
Industrial use	Solvents (for cleaning or degreasing)	Cold cleaner	Cold cleaning - maintenance (manual spray; spray sink; dip tank)	Mist	Dermal/ Inhalation	Workers, ONU	No	Mist generation not expected during degreasing operations.
				Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. However, repeat contact or dermal immersion may occur.
				Vapor	Inhalation	Workers	Yes	Inhalation exposure is expected for cold cleaning activities. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.

Life Cycle Stage	Category	Subcategory	Release / Exposure Scenario	Exposure Pathway	Exposure Route	Receptor / Population	Proposed for Further Risk Evaluation	Rationale for Further Evaluation / no Further Evaluation
Industrial use	Processing aids	Pesticide, fertilizer and other agricultural chemical manufacturing; and petrochemical manufacturing	Industrial processing aid	Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical
				Vapor	Inhalation	ONU	Yes	Inhalation exposure is expected for cold cleaning activities. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Mist	Dermal/ Inhalation	Workers, ONU	Yes	EPA will further evaluate to determine if mist generation is applicable.
				Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. Additionally, EPA will need additional information to fully understand the use of perchloroethylene in this scenario to determine potential for dermal exposure.
				Vapor	Inhalation	Workers	Yes	perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed. However, EPA will need additional information to fully understand the use of perchloroethylene in this scenario to determine potential for inhalation exposure.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed. However, EPA will need additional information to fully understand the use of perchloroethylene in this scenario to determine potential for inhalation exposure.
				Mist	Dermal/ Inhalation	Workers, ONU	No	Mist generation not expected during use of industrial processing aid.

Life Cycle Stage	Category	Subcategory	Release / Exposure Scenario	Exposure Pathway	Exposure Route	Receptor / Population	Proposed for Further Risk Evaluation	Rationale for Further Evaluation / no Further Evaluation
Industrial use	Other uses	Textile processing; wood furniture manufacturing; laboratory chemicals; and foundry applications	See Table XX for specific scenario corresponding to the condition of use.	Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. However, repeat contact may occur for some miscellaneous conditions of use.
				Vapor	Inhalation	Workers	Yes	perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Mist	Dermal/ Inhalation	Workers, ONU	Yes	EPA will further analyze to determine if mist generation is applicable to specific conditions of use in this scenario.
Industrial / commercial / consumer use	Solvents (for cleaning or degreasing)	Aerosol spray degreaser/ cleaner	Aerosol use in degreasing/ cleaning	Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. However, repeat contact may occur.
				Vapor	Inhalation	Workers	Yes	Inhalation exposure is expected for aerosol degreasing activities. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	Inhalation exposure is expected for aerosol degreasing activities. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Mist	Dermal/ Inhalation	Workers, ONU	Yes	Mist generation expected for aerosol applications.

Life Cycle Stage	Category	Subcategory	Release / Exposure Scenario	Exposure Pathway	Exposure Route	Receptor / Population	Proposed for Further Risk Evaluation	Rationale for Further Evaluation / no Further Evaluation
Industrial / commercial / consumer use	Solvents (for cleaning or degreasing); and cleaning and furniture care products	Dry cleaning solvent; and spot cleaner	Industrial and commercial dry cleaning	Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. However, repeat contact may occur.
				Vapor	Inhalation	Workers	Yes	Inhalation exposure is expected for dry cleaning activities. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	Inhalation exposure is expected for dry cleaning activities. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Mist	Dermal/ Inhalation	Workers, ONU	Yes	Mist generation expected for spot cleaning.
				Indoor vapor	Dermal	Co-located population	No	Exposure via dermal and oral routes may be unlikely.
				Indoor vapor	Oral	Co-located population	No	Exposure via dermal and oral routes may be unlikely.
				Indoor vapor	Inhalation	Co-located population	No	EPA expects persons living in residences co-located with dry cleaners to be exposed to vapor. Exposure will occur primarily via the inhalation route. However, the NESHAP for the use of perchloroethylene in Dry Cleaners required the phase-out of perchloroethylene in co-located buildings by 2020.

Life Cycle Stage	Category	Subcategory	Release / Exposure Scenario	Exposure Pathway	Exposure Route	Receptor / Population	Proposed for Further Risk Evaluation	Rationale for Further Evaluation / no Further Evaluation
Industrial / commercial / consumer use	Lubricants and greases	Lubricants and greases (e.g., penetrating lubricants, cutting tool coolants, aerosol lubricants)	Aerosol application of lubricants to substrates	Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. However, repeat contact may occur.
				Vapor	Inhalation	Workers	Yes	Inhalation exposure is expected for application of aerosol lubricants. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	Inhalation exposure is expected for application of aerosol lubricants. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
Industrial / commercial / consumer use	Lubricants and greases	Metalworking lubricants (cutting fluids)	Use of metalworking fluids (cutting fluids)	Mist	Dermal/ Inhalation	Workers, ONU	Yes	Mist generation expected for aerosol applications.
				Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. However, repeat contact may occur.
				Vapor	Inhalation	Workers	Yes	Inhalation exposure is expected for use of metalworking fluids. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	Inhalation exposure is expected for use of metalworking fluids. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Mist	Dermal/ Inhalation	Workers, ONU	Yes	Mist generation expected from use of metalworking fluids.

Life Cycle Stage	Category	Subcategory	Release / Exposure Scenario	Exposure Pathway	Exposure Route	Receptor / Population	Proposed for Further Risk Evaluation	Rationale for Further Evaluation / no Further Evaluation
Industrial / commercial / consumer use	Adhesives and sealants	Solvent-based adhesives and sealants; and light repair adhesives	Spray adhesive application; and other adhesive and sealant applications (e.g. roll)	Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. However, repeat contact may occur.
				Vapor	Inhalation	Workers	Yes	Inhalation exposure is expected from adhesive applications. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	Inhalation exposure is expected from adhesive applications. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
Industrial / commercial / consumer use	Paints and coatings including paint and coating removers	Solvent-based paints and coatings	Spray coating application; and other paint and coating applications (e.g. roll)	Mist	Dermal/ Inhalation	Workers, ONU	Yes	Mist generation expected for spray and roll applications. EPA will further analyze to determine if mist generation is applicable for each adhesive/sealant product.
				Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. However, repeat contact may occur.
				Vapor	Inhalation	Workers	Yes	Inhalation exposure is expected from coating applications. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
Industrial / commercial / consumer use				Vapor	Inhalation	ONU	Yes	Inhalation exposure is expected from coating applications. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.

Life Cycle Stage	Category	Subcategory	Release / Exposure Scenario	Exposure Pathway	Exposure Route	Receptor / Population	Proposed for Further Risk Evaluation	Rationale for Further Evaluation / no Further Evaluation
Commercial / consumer use	Cleaning and furniture care products	Automotive care products (e.g., engine degreaser and brake cleaner)	Commercial auto repair/ servicing	Mist	Dermal/ Inhalation	Workers, ONU	Yes	Mist generation expected for spray and roll applications. EPA will further analyze to determine if mist generation is applicable for each paint/coating product.
				Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. However, repeat contact may occur.
				Vapor	Inhalation	Workers	Yes	Inhalation exposure is expected for aerosol degreasing activities. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
Commercial / consumer use	Cleaning and furniture care products	Non-aerosol cleaner	Wipe cleaning	Vapor	Inhalation	ONU	Yes	Inhalation exposure is expected for aerosol degreasing activities. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Mist	Dermal/ Inhalation	Workers, ONU	Yes	Mist generation expected for aerosol applications.
				Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. However, repeat contact may occur.
				Vapor	Inhalation	Workers	Yes	Inhalation exposure is expected from wipe cleaning. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
Commercial / consumer use	Cleaning and furniture care products	Non-aerosol cleaner	Wipe cleaning	Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.

Life Cycle Stage	Category	Subcategory	Release / Exposure Scenario	Exposure Pathway	Exposure Route	Receptor / Population	Proposed for Further Risk Evaluation	Rationale for Further Evaluation / no Further Evaluation
Commercial / consumer use	Cleaning and furniture care products	Carpet cleaner	Commercial carpet spotting and stain removers	Vapor	Inhalation	ONU	Yes	Inhalation exposure is expected from wipe cleaning. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Mist	Dermal/ Inhalation	Workers, ONU	No	Mist generation not expected during wipe cleaning.
				Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. However, repeat contact may occur.
				Vapor	Inhalation	Workers	Yes	Inhalation exposure is expected from carpet cleaning. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	Inhalation exposure is expected from carpet cleaning. perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Mist	Dermal/ Inhalation	Workers, ONU	Yes	EPA will further analyze to determine if mist generation is applicable.

Life Cycle Stage	Category	Subcategory	Release / Exposure Scenario	Exposure Pathway	Exposure Route	Receptor / Population	Proposed for Further Risk Evaluation	Rationale for Further Evaluation / no Further Evaluation
Commercial / consumer use	Other uses	Laboratory chemicals; metal and stone polishes; inks and ink removal products; welding; photographic film; and mold cleaning, release and protectant products	See Table XX for specific scenario corresponding to the condition of use.	Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. However, repeat contact may occur for some miscellaneous conditions of use.
				Vapor	Inhalation	Workers	Yes	perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
Disposal	Waste Handling, Treatment and Disposal	Disposal of perchloroethylene wastes	Worker handling of wastes	Mist	Dermal/ Inhalation	Workers, ONU	Yes	EPA will further analyze to determine if mist generation is applicable to specific conditions of use in this scenario.
				Liquid Contact	Dermal	Workers	Yes	Contact time with skin is expected to be <10 min due to volatilization. Frequency of exposure and the potential for dermal immersion needs to be further analyzed.
				Vapor	Inhalation	Workers	Yes	perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Liquid Contact	Dermal	ONU	No	Dermal exposure is expected to be primarily to workers directly involved in working with the chemical.
				Vapor	Inhalation	ONU	Yes	perchloroethylene is semi-volatile (VP = 18.5 mmHg) at room temperature, inhalation pathway should be further analyzed.
				Mist	Dermal/ Inhalation	Workers, ONU	No	Mist generation not expected from waste handling.

## Appendix D SUPPORTING TABLE FOR CONSUMER ACTIVITIES AND USES CONCEPTUAL MODEL

**Table\_Apx D-1. Consumer Activities and Uses Conceptual Model Supporting Table**

Categories of Conditions of Use for Consumer Activities	Exposure Pathway	Exposure Pathway	Receptor	Rationale for Inclusion
Cleaning and Furniture Care Products; Lubricants and Greases; Adhesives and Sealants; Paints and Coatings; Dry Cleaned Clothing and Textiles; Other Uses	Liquid Contact	Dermal	Consumer	Perchloroethylene is found in consumer products, dermal contact to perchloroethylene containing liquids will be further analyzed for consumer exposure
	Vapor/Mist (Includes Liquid Contact)	Inhalation (includes Oral)	Consumer, Bystanders	Perchloroethylene is found in consumer products and may volatilize, depending on product formulation and percent composition. Inhalation exposure to perchloroethylene containing liquids will be further analyzed for consumers and bystanders

ONU = Occupational Non-User

## Appendix E      SUPPORTING TABLE FOR ENVIRONMENTAL RELEASES AND WASTES CONCEPTUAL MODEL

**Table\_Apx E-1. Environmental Releases and Wastes Conceptual Model Supporting Table**

Life Cycle Stage	Release Category	Release/ Exposure Scenario	Exposure Pathway/ Media	Exposure Routes	Receptor/ Population	Proposed for Further Risk Evaluation	Rationale for Further Evaluation/ no Further
Manufacture and Import; Processing as Reactant/ Intermediate; Incorporation into Formulation; Mixture or Reaction Product; Incorporation into Article; Use of Product of Article; Repackaging; Recycling	Wastewater or Liquid Wastes	Industrial Pre-Treatment and Industrial WWT and/or Municipal WWT	Water, Sediment	Water	Aquatic Species	Yes	Perchloroethylene toxicity to aquatic and sediment dwelling aquatic species is expected to be low-moderate; perchloroethylene has low bioaccumulation potential, and conservative estimates for surface water and sediment concentrations due to current TSCA uses were below identified COCs

## Appendix F INCLUSION AND EXCLUSION CRITERIA FOR FULL TEXT SCREENING

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Appendix F contains the eligibility criteria for various data streams informing the TSCA risk evaluation: environmental fate; engineering and occupational exposure; exposure to consumers; and human health hazard. The criteria are applied to the *on-topic* references that were identified following title and abstract screening of the comprehensive search results published on June 22, 2017.

Systematic reviews typically describe the study eligibility criteria in the form of PECO statements or a modified framework. PECO stands for Population, Exposure, Comparator and Outcome and the approach is used to formulate explicit and detailed criteria about those characteristics in the publication that should be present in order to be eligible for inclusion in the review. EPA/OPPT adopted the PECO approach to guide the inclusion/exclusion decisions during full text screening.

Inclusion and exclusion criteria were also used during the title and abstract screening, and documentation about the criteria can be found in the *Strategy for Conducting Literature Searches* document published in June 2017 along with each of the TSCA Scope documents. The list of *on-topic* references resulting from the title and abstract screening is undergoing full text screening using the criteria in the PECO statements. The overall objective of the screening process is to select the most relevant evidence for the TSCA risk evaluation. As a general rule, EPA is excluding non-English data/information sources and will translate on a case by case basis.

The inclusion and exclusion criteria for ecotoxicological data have been documented in the ECOTOX SOPs. The criteria can be found at <https://cfpub.epa.gov/ecotox/help.cfm?helptabs=tab4>) and in the *Strategy for Conducting Literature Searches* document published along with each of the TSCA Scope documents.

Since full text screening commenced right after the publication of the TSCA Scope document, the criteria were set to be broad to capture relevant information that would support the initial risk evaluation. Thus, the inclusion and exclusion criteria for full text screening do not reflect the refinements to the conceptual model and analysis plan resulting from problem formulation. As part of the iterative process, EPA is in the process of refining the results of the full text screening to incorporate the changes in information/data needs to support the revised risk evaluation.

These refinements will include changes to the inclusion and exclusion criteria discussed in this appendix to better support the revised risk evaluation and will likely reduce the number of data/information sources that will undergo evaluation.

### F.1 Inclusion Criteria for Data Sources Reporting Environmental Fate Data

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EPA/OPPT developed a generic PESO statement to guide the full text screening of environmental fate data sources. PESO stands for Pathways and Processes, Exposure, Setting or Scenario, and Outcomes. Subsequent versions of the PESO statement may be produced throughout the process of screening and evaluating data for the chemicals undergoing TSCA risk evaluation. Studies that comply with the inclusion criteria in the PESO statement are eligible for inclusion, considered for evaluation, and possibly included in the environmental fate assessment. On the other hand, data sources are excluded if they do not meet the criteria in the PESO statement.

EPA describes the expected exposure pathways to human receptors from consumer uses of perchloroethylene that EPA plans to include in the risk evaluation in Section 2.5.2. EPA expects that the primary route of exposure for consumers will be via inhalation. There may also be dermal exposure. Environmental fate data will not be used to further assess these exposure pathways as they are expected to occur in the indoor environment.

During problem formulation, exposure pathways to human and ecological receptors from environmental releases and waste stream associated with industrial and commercial activities will not be further analyzed in risk evaluation. For a description of the rationale behind this conclusion, see Section 2.5.3.2. In the absence of exposure pathways for further analysis, environmental fate data will not be further evaluated. Therefore, PESO statements describing fate endpoints, associated processes, media and exposure pathways that were considered in the development of the environmental fate assessment for perchloroethylene will not be presented.

## F.2 Inclusion Criteria for Data Sources Reporting Engineering and Occupational Exposure Data

EPA/OPPT developed a generic RESO statement to guide the full text screening of engineering and occupational exposure literature (Table Apx F-3). RESO stands for Receptors, Exposure, Setting or Scenario, and Outcomes. Subsequent versions of the RESO statement may be produced throughout the process of screening and evaluating data for the chemicals undergoing TSCA risk evaluation. Studies that comply with the inclusion criteria specified in the RESO statement will be eligible for inclusion, considered for evaluation, and possibly included in the environmental release and occupational exposure assessments, while those that do not meet these criteria will be excluded.

The RESO statement should be used along with the engineering and occupational exposure data needs table (Table Apx F-3) when screening the literature.

Since full text screening commenced right after the publication of the TSCA Scope document, the criteria for engineering and occupational exposure data were set to be broad to capture relevant information that would support the risk evaluation. Thus, the inclusion and exclusion criteria for full text screening do not reflect the refinements to the conceptual model and analysis plan resulting from problem formulation. As part of the iterative process, EPA is in the process of refining the results of the full text screening to incorporate the changes in information/data needs to support the revised risk evaluation.

**Table Apx F-1. Inclusion Criteria for Data Sources Reporting Engineering and Occupational Exposure Data**

RESO Element	Evidence
<u>Receptors</u>	<ul style="list-style-type: none"> <li>• <b><u>Humans:</u></b> Workers, including occupational non-users</li> <li>• <b><u>Environment:</u></b> Aquatic ecological receptors (release estimates input to Exposure)</li> </ul> <p>Please refer to the conceptual models for more information about the ecological and human receptors included in the TSCA risk evaluation.</p>
<u>Exposure</u>	<ul style="list-style-type: none"> <li>• Worker exposure to and occupational environmental releases of the chemical substance of interest <ul style="list-style-type: none"> <li>○ Dermal and inhalation exposure routes (as indicated in the conceptual model)</li> <li>○ Surface water (as indicated in the conceptual model)</li> </ul> </li> </ul> <p>Please refer to the conceptual models for more information about the routes and media/pathways included in the TSCA risk evaluation.</p>
<u>Setting or Scenario</u>	<ul style="list-style-type: none"> <li>• Any occupational setting or scenario resulting in worker exposure and environmental releases (includes all manufacturing, processing, use, disposal indicated in Table A-3).</li> </ul>
<u>Outcomes</u>	<ul style="list-style-type: none"> <li>• Quantitative estimates* of worker exposures and of environmental releases from occupational settings</li> <li>• General information and data related and relevant to the occupational estimates*</li> </ul>

\* Metrics (e.g., mg/kg/day or mg/m<sup>3</sup> for worker exposures, kg/site/day for releases) are determined by toxicologists for worker exposures and by exposure assessors for releases; also, the Engineering, Release, and Occupational Exposure Data Needs (Table 2) provides a list of related and relevant general information.

**Table\_Apx F-2. Engineering, Environmental Release and Occupational Data Necessary to Develop the Environmental Release and Occupational Exposure Assessments**

Objective Determined during Scoping	Type of Data
General Engineering Assessment (may apply for either or both Occupational Exposures and / or Environmental Releases)	<ol style="list-style-type: none"> <li>1. Description of the life cycle of the chemical(s) of interest, from manufacture to end-of-life (e.g., each manufacturing, processing, or use step), and material flow between the industrial and commercial life cycle stages. [Tags: Life cycle description, Life cycle diagram]<sup>a</sup></li> <li>2. The total annual U.S. volume (lb/yr or kg/yr) of the chemical(s) of interest manufactured, imported, processed, and used; and the share of total annual manufacturing and import volume that is processed or used in each life cycle step. [Tags: Production volume, Import volume, Use volume, Percent PV]<sup>a</sup></li> <li>3. Description of processes, equipment, unit operations, and material flows and frequencies (lb/site-day or kg/site-day and days/yr; lb/site-batch and batches/yr) of the chemical(s) of interest during each industrial/commercial life cycle step. Note: if available, include weight fractions of the chemicals (s) of interest and material flows of all associated primary chemicals (especially water). [Tags: Process description, Process material flow rate, Annual operating days, Annual batches, Weight fractions (for each of above, manufacture, import, processing, use)]<sup>a</sup></li> <li>4. Basic chemical properties relevant for assessing exposures and releases, e.g., molecular weight, normal boiling point, melting point, physical forms, and room temperature vapor pressure. [Tags: Molecular weight, Boiling point, Melting point, Physical form, Vapor pressure, Water solubility]<sup>a</sup></li> <li>5. Number of sites that manufacture, process, or use the chemical(s) of interest for each industrial/commercial life cycle step and site locations. [Tags: Numbers of sites (manufacture, import, processing, use), Site locations]<sup>a</sup></li> </ol>
Occupational Exposures	<ol style="list-style-type: none"> <li>6. Description of worker activities with exposure potential during the manufacture, processing, or use of the chemical(s) of interest in each industrial/commercial life cycle stage. [Tags: Worker activities (manufacture, import, processing, use)]<sup>a</sup></li> <li>7. Potential routes of exposure (e.g., inhalation, dermal). [Tags: Routes of exposure (manufacture, import, processing, use)]<sup>a</sup></li> <li>8. Physical form of the chemical(s) of interest for each exposure route (e.g., liquid, vapor, mist) and activity. [Tags: Physical form during worker activities (manufacture, import, processing, use)]<sup>a</sup></li> <li>9. Breathing zone (personal sample) measurements of occupational exposures to the chemical(s) of interest, measured as time-weighted averages (TWAs), short-term exposures, or peak exposures in each occupational life cycle stage (or in a workplace scenario similar to an occupational life cycle stage). [Tags: PBZ measurements (manufacture, import, processing, use)]<sup>a</sup></li> <li>10. Area or stationary measurements of airborne concentrations of the chemical(s) of interest in each occupational setting and life cycle stage (or in a workplace scenario similar to the life cycle stage of interest). [Tags: Area measurements (manufacture, import, processing, use)]<sup>a</sup></li> <li>11. For solids, bulk and dust particle size characterization data. [Tags: PSD measurements (manufacture, import, processing, use)]<sup>a</sup></li> <li>12. Dermal exposure data. [Tags: Dermal measurements (manufacture, import, processing, use)]</li> <li>13. Data needs associated with mathematical modeling (will be determined on a case-by-case basis). [Tags: Worker exposure modeling data needs (manufacture, import, processing, use)]<sup>a</sup></li> <li>14. Exposure duration (hr/day). [Tags: Worker exposure durations (manufacture, import, processing, use)]<sup>a</sup></li> <li>15. Exposure frequency (days/yr). [Tags: Worker exposure frequencies (manufacture, import, processing, use)]<sup>a</sup></li> <li>16. Number of workers who potentially handle or have exposure to the chemical(s) of interest in each occupational life cycle stage. [Tags: Numbers of workers exposed (manufacture, import, processing, use)]<sup>a</sup></li> <li>17. Personal protective equipment (PPE) types employed by the industries within scope. [Tags: Worker PPE (manufacture, import, processing, use)]<sup>a</sup></li> <li>18. Engineering controls employed to reduce occupational exposures in each occupational life cycle stage (or in a workplace scenario similar to the life cycle stage of interest), and associated data or estimates of</li> </ol>

Objective Determined during Scoping	Type of Data
	exposure reductions. [Tags: Engineering controls (manufacture, import, processing, use), Engineering control effectiveness data] <sup>a</sup>
Environmental Releases	19. Description of relevant sources of potential environmental releases, including cleaning of residues from process equipment and transport containers, involved during the manufacture, processing, or use of the chemical(s) of interest in each life cycle stage. [Tags: Release sources (manufacture, import, processing, use)] <sup>a</sup> 20. Estimated mass (lb or kg) of the chemical(s) of interest released from industrial and commercial sites to each relevant environmental media (air, water, land) and treatment and disposal methods (POTW, incineration, landfill), including releases per site and aggregated over all sites (annual release rates, daily release rates) [Tags: Release rates (manufacture, import, processing, use)] <sup>a</sup> 21. Release or emission factors. [Tags: Emission factors (manufacture, import, processing, use)] <sup>a</sup> 22. Number of release days per year. [Tags: Release frequencies (manufacture, import, processing, use)] <sup>a</sup> 23. Data needs associated with mathematical modeling (will be determined on a case-by-case basis). [Tags: Release modeling data needs (manufacture, import, processing, use)] <sup>a</sup> 24. Waste treatment methods and pollution control devices employed by the industries within scope and associated data on release/emission reductions. [Tags: Treatment/ emission controls (manufacture, import, processing, use), Treatment/ emission controls removal/ effectiveness data] <sup>a</sup>
<b>Notes:</b> <sup>a</sup> These are the tags included in the full text screening form. The screener makes a selection from these specific tags, which describe more specific types of data or information. <b>Abbreviations:</b> hr=Hour kg=Kilogram(s) lb=Pound(s) yr=Year PV=Particle volume PBZ= POTW=Publicly owned treatment works PPE=Personal protection equipment PSD=Particle size distribution TWA=Time-weighted average	

### F.3 Inclusion Criteria for Data Sources Reporting Exposure Data on Consumers and Ecological Receptors

EPA/OPPT developed PECO statements to guide the full text screening of exposure data/information for human (i.e., consumers, potentially exposed or susceptible subpopulations) and ecological receptors. Subsequent versions of the PECO statements may be produced throughout the process of screening and evaluating data for the chemicals undergoing TSCA risk evaluation. Studies that comply with the inclusion criteria in the PECO statement are eligible for inclusion, considered for evaluation, and possibly included in the exposure assessment. On the other hand, data sources are excluded if they do not meet the criteria in the PECO statement. The perchloroethylene-specific PECO is provided in Table\_Apx F-5.

Since full text screening commenced right after the publication of the TSCA Scope document, the criteria for exposure data were set to be broad to capture relevant information that would support the risk evaluation. Thus, the inclusion and exclusion criteria for full text screening do not reflect the refinements to the conceptual model and analysis plan resulting from problem formulation. As part of the iterative process, EPA is in the process of refining the results of the full text screening to incorporate the changes in information/data needs to support the risk evaluation.

**Table\_Apx F-3. Inclusion Criteria for the Data Sources Reporting Perchloroethylene Exposure Data on Consumers and Ecological Receptors**

PECO Element	Evidence
<u>P</u> opulation	<b><u>Human:</u></b> Consumers; bystanders in the home; children; infants; pregnant women; lactating women.
	<b><u>Ecological:</u></b> Aquatic species.
<u>E</u> xposure	<b>Expected Primary Exposure Sources, Pathways, Routes:</b> <ul style="list-style-type: none"> <li>• <b><u>Sources:</u></b> Industrial and commercial activities involving non-closed systems producing releases to surface water; consumer uses in the home producing releases to air and dermal contact</li> <li>• <b><u>Pathways:</u></b> indoor air, direct contact and surface water.</li> <li>• <b><u>Routes of Exposure:</u></b> Inhalation via indoor air (consumer and bystander populations) and incidental ingestion of aerosols and mists; dermal exposure via direct contact with consumer products containing perchloroethylene</li> </ul>
Comparator (Scenario)	<b><u>Human:</u></b> Consider media-specific background exposure scenarios and use/source specific exposure scenarios as well as which receptors are and are not reasonably exposed across the projected exposure scenarios.
	<b><u>Ecological:</u></b> Consider media-specific background exposure scenarios and use/source specific exposure scenarios as well as which receptors are and are not reasonably exposed across the projected exposure scenarios.
<u>O</u> utcomes for Exposure Concentration or Dose	<b><u>Human:</u></b> Acute, subchronic, and/or chronic external dose estimates (mg/kg/day); acute, subchronic, and/or chronic air and water concentration estimates (mg/m <sup>3</sup> or mg/L). Both external potential dose and internal dose based on biomonitoring and reverse dosimetry mg/kg/day will be considered.
	<b><u>Ecological:</u></b> A wide range of ecological receptors will be considered (range depending on available ecotoxicity data).

**Abbreviations:**

Kg=Kilogram(s)  
Mg=Milligram(s)  
M<sup>3</sup>=Cubic meter  
L=Liter(s)

## F.4 Inclusion Criteria for Data Sources Reporting Ecological Hazards

Table\_Apx F-4. Ecological Hazard PECO (Populations, Exposures, Comparators, Outcomes) Statement for Perchloroethylene

PECO Element	Evidence
<b><u>Population</u></b>	Tests of the single chemical ( <i>i.e.</i> , PERC) on live, whole, taxonomically verifiable organisms, (including gametes, embryos, or plant or fungal sections capable of forming whole, new organisms) and <i>in vitro</i> systems.
<b><u>Exposure</u></b>	<b><u>Chemical:</u></b> Tests using single, verifiable chemical, administered through an acceptable route. Must also be used in relevant environmental exposure studies, as determined by usual toxicology standards.
	<b><u>Concentration:</u></b> Study must specify the amount of chemical the organisms were exposed to, either as a concentration in the environment when administered via environmental media (e.g. air, soil, water, or sediment), or as a dosage when introduced directly into or on the organism via oral (e.g. diet or gavage), topical or injection routes.
	<b><u>Duration:</u></b> Study must specify the duration from the time of initial exposure to the time of measurement. May be imprecise, as in “less than 6 months,” “one growing season,” or “from 3 to 5 weeks.”
<b><u>Comparator</u></b>	Study must have controls or reference locations.
<b><u>Outcome</u></b>	Measurable/observable biological effect(s) (e.g. mortality, behavioral, population, biochemical, cellular, physiological, growth, reproduction, etc.) of an acceptable organism to a chemical.

## F.5 Inclusion Criteria for Data Sources Reporting Human Health Hazards

EPA/OPPT developed a perchloroethylene-specific PECO statement (Table\_Apx F-7) to guide the full text screening of the human health hazard literature. Subsequent versions of the PECO statements may be produced throughout the process of screening and evaluating data for the chemicals undergoing TSCA risk evaluation. Studies that comply with the criteria specified in the PECO statement will be eligible for inclusion, considered for evaluation, and possibly included in the human health hazard assessment, while those that do not meet these criteria will be excluded according to the exclusion criteria.

In general, the PECO statements were based on (1) information accompanying the TSCA Scope document, and (2) preliminary review of the health effects literature from authoritative sources cited in the TSCA Scope documents. When applicable, these authoritative sources (e.g., IRIS assessments, EPA/OPPT’s Work Plan Problem Formulations or risk assessments) will serve as starting points to identify PECO-relevant studies.

**Table\_Apx F-5. Inclusion and Exclusion Criteria for Data Sources Reporting Human Health Hazards Related to Perchloroethylene (PERC)<sup>a</sup>**

PECO Element	Evidence Stream	Papers/Features Included	Papers/Features Excluded
<b>Population <sup>b</sup></b>	<i>Human</i>	<ul style="list-style-type: none"> <li>Any population</li> <li>All lifestages</li> <li>All study designs, includes: <ul style="list-style-type: none"> <li>Controlled exposure, cohort, case-control, cross-sectional, case-crossover, ecological, case studies and case series</li> </ul> </li> </ul>	
	<i>Animal</i>	<ul style="list-style-type: none"> <li>All non-human whole-organism mammalian species</li> <li>All lifestages</li> </ul>	<ul style="list-style-type: none"> <li>Non-mammalian species</li> </ul>
<b>Exposure</b>	<i>Human</i>	<ul style="list-style-type: none"> <li>Exposure based on administered dose or concentration of perchloroethylene, biomonitoring data (e.g., urine, blood or other specimens), environmental or occupational-setting monitoring data (e.g., air, water levels), job title or residence</li> <li>Any metabolites of interest as identified in biomonitoring studies</li> <li>Exposure identified as <i>or presumed to be</i> from oral, dermal, inhalation routes</li> <li>Any number of exposure groups</li> <li>Quantitative, semi-quantitative or qualitative estimates of exposure</li> <li>Exposures to multiple chemicals/mixtures only if perchloroethylene or related metabolites were independently measured and analyzed</li> </ul>	<ul style="list-style-type: none"> <li>Route of exposure <i>not</i> by inhalation, oral or dermal type (e.g., intraperitoneal, injection)</li> <li>Multiple chemical/mixture exposures with no independent measurement of or exposure to perchloroethylene (or related metabolite)</li> </ul>
	<i>Animal</i>	<ul style="list-style-type: none"> <li>A minimum of 2 quantitative dose or concentration levels of perchloroethylene plus a negative control group <sup>a</sup></li> <li>Acute, subchronic, chronic exposure from oral, dermal, inhalation routes</li> <li>Exposure to perchloroethylene only (no chemical mixtures)</li> </ul>	<ul style="list-style-type: none"> <li>Only 1 quantitative dose or concentration level in addition to the control <sup>a</sup></li> <li>Route of exposure <i>not</i> by inhalation, oral or dermal type (e.g., intraperitoneal, injection)</li> <li>No duration of exposure stated</li> <li>Exposure to perchloroethylene in a chemical mixture</li> </ul>
<b>Comparator</b>	<i>Human</i>	<ul style="list-style-type: none"> <li>Any or no comparison</li> </ul>	
	<i>Animal</i>	<ul style="list-style-type: none"> <li>Negative controls that are vehicle-only treatment and/or no treatment</li> </ul>	<ul style="list-style-type: none"> <li>Negative controls <i>other than</i> vehicle-only treatment or no treatment</li> </ul>
<b>Outcome</b>	<i>Human and Animal</i>	<ul style="list-style-type: none"> <li>Endpoints described in the perchloroethylene scope document <sup>c</sup>: <ul style="list-style-type: none"> <li>Acute toxicity</li> <li>Neurotoxicity</li> <li>Liver toxicity</li> <li>Reproductive/developmental toxicity</li> <li>Irritation</li> <li>Cancer</li> </ul> </li> <li>Other endpoints <sup>d</sup></li> </ul>	
<b>General Considerations</b>		<b>Papers/Features Included</b>	<b>Papers/Features Excluded</b>
		<ul style="list-style-type: none"> <li>Written in English <sup>e</sup></li> </ul>	<ul style="list-style-type: none"> <li>Not written in English <sup>e</sup></li> </ul>

PECO Element	Evidence Stream	Papers/Features Included	Papers/Features Excluded
		<ul style="list-style-type: none"> <li>• Reports a primary source or meta-analysis <sup>a</sup></li> <li>• Full-text available</li> <li>• Reports both perchloroethylene exposure <u>and</u> a health outcome</li> </ul>	<ul style="list-style-type: none"> <li>• Reports secondary source (e.g., review papers) <sup>a</sup></li> <li>• No full-text available (e.g., only a study description/abstract, out-of-print text)</li> <li>• Reports a perchloroethylene-related exposure <u>or</u> a health outcome, but not both (e.g. incidence, prevalence report)</li> </ul>

# **RECORD OF DECISION**

## **SAN JACINTO RIVER WASTE PITS**

**HARRIS COUNTY, TEXAS**

**EPA ID: TXN000606611**



**U.S. ENVIRONMENTAL PROTECTION AGENCY**

**REGION 6**

**DALLAS, TEXAS**

**OCTOBER 2017**

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## LIST OF ACRONYMS AND ABBREVIATIONS

95UCL °F	95 percent upper confidence limit degrees Fahrenheit
Anchor ARAR	Anchor QEA, LLC applicable or relevant and appropriate requirement
BERA BHHRA BMP	baseline ecological risk assessment baseline human health risk assessment best management practice
CDI CERCLA	chronic daily intake Comprehensive Environmental Response, Compensation, and Liability Act
CFR cfs COC COPC COPEC CWA cy	Code of Federal Regulations cubic feet per second chemical of concern chemical of potential concern chemical of potential ecological concern Clean Water Act cubic yard(s)
Dioxins	polychlorinated dibenzo-p-dioxins
EPA	U.S. Environmental Protection Agency
FCA FS furans	fish collection area feasibility study polychlorinated dibenzofurans
HI HpCDD HQ HxCDF	hazard index heptachlorodibenzo-p-dioxin hazard quotient hexachlorodibenzofuran
I-10 IC Integral IRIS	Interstate Highway 10 institutional control Integral Consulting Inc. Integrated Risk Information System
Mg/kg MNR MSL	milligram(s) per kilogram monitored natural recovery mean sea level
NCP	National Oil and Hazardous Substances Pollution Contingency Plan

**LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)**

ng/kg	nanogram(s) per kilogram
NOAEL	no observed adverse effects level
NPL	National Priorities List
OCDD	octachlorinated dibenzo-p-dioxin
PCB	polychlorinated biphenyl
pg/kg	picogram(s) per kilogram
pg/L	picogram(s) per liter
PRG	preliminary remediation goal
RAO	remedial action objective
RfD	reference dose
RI	remedial investigation
ROD	Record of Decision
SF	slope factor
Site	San Jacinto River Waste Pits
SLERA	screening level ecological risk assessment
SPME	solid-phase micro extraction
S/S	solidification and stabilization
SVOC	semivolatile organic compound
TCEQ	Texas Commission on Environmental Quality
TCRA	Time Critical Removal Action
TCDD	tetrachlorodibenzo-p-dioxin
TCDF	tetrachlorodibenzofuran
TDSHS	Texas Department of State Health Services
TEQ	2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalents
TEQ <sub>P, M</sub>	dioxin-like PCB congeners toxicity equivalents calculated using toxicity equivalency factors for mammals
TMDL	total maximum daily load
TOC	total organic carbon
TPWD	Texas Parks and Wildlife Department
TxDOT	Texas Department of Transportation
UAO	Unilateral Administrative Order
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Society
VOC	volatile organic compound

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## **PART 1: THE DECLARATION**

### **1.1 SITE NAME AND LOCATION**

The San Jacinto River Waste Pits Superfund Site is located in Channelview, Harris County, Texas (Site). The U.S. Environmental Protection Agency (EPA) Superfund Database Identification Number is TXN000606611. This Site remedial response is a single operable unit, and all areas and media within the site are addressed in this Record of Decision (ROD) document.

### **1.2 STATEMENT OF BASIS AND PURPOSE**

This decision document presents the Selected Remedy for the San Jacinto River Waste Pits Site in Harris County, Texas. The Selected Remedy was chosen in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), 42 U.S. Code §9601 et seq., as amended by the Superfund Amendments and Reauthorization Act of 1986; and, to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) Part 300, as amended. This decision is based on the administrative record for the site, which has been developed in accordance with Section 133(k) of CERCLA, 42 U.S. Code §9613(k).

The State of Texas, acting through the Texas Commission on Environmental Quality (TCEQ), was provided the opportunity to review and comment on the Selected Remedy.

### **1.3 ASSESSMENT OF THE SITE**

The response action selected in this ROD is necessary to protect the public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment and pollutants or contaminants which may present an imminent and substantial endangerment to the public health or welfare.

### **1.4 DESCRIPTION OF THE SELECTED REMEDY**

The Selected Remedy is a final action for the San Jacinto River Waste Pits Site. It addresses unacceptable human health risks associated with consumption of fish and direct contact (skin contact and incidental ingestion) with the waste material from the Site. It also addresses Site-related ecological risks to bottom-dwelling organisms (benthic invertebrates) from exposure to sediment and waste material.

The overall strategy for addressing contamination at the Site includes excavation and off-site disposal of source materials and contaminated soils from impoundments in and adjacent to the San Jacinto River. There are impoundments located both north and south of Interstate 10. Institutional Controls (ICs) will be used to prevent disturbance of the certain areas (e.g., dredging and anchoring in the Sand Separation Area, and construction, and excavation in the southern impoundment). Monitored natural recovery (MNR) will be used for sediment in the nearby sand

separation area to ensure remedy protectiveness in the aquatic environment. The Selected Remedy includes the following major components:

- Removal of a portion of the existing temporary armored cap installed under the time-critical removal action (TCRA).
- Removal of approximately 162,000 cubic yards (cy) of waste material exceeding the paper mill waste material cleanup goal of 30 nanograms per kilogram (ng/kg) 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxicity equivalent (TEQ) that is located beneath the armored cap in the northern impoundment. The waste material will be stabilized as necessary to meet the appropriate requirements at a permitted disposal facility.
- Excavation of approximately 50,000 cy of waste material exceeding the paper mill waste material and soil cleanup goal for the southern impoundment of 240 ng/kg TEQ to a depth of 10 feet below grade in the peninsula south of I-10.

## 1.5 STATUTORY DETERMINATIONS

The selected remedy meets the requirements for remedial actions set forth in Section 121 of CERCLA, 42 U.S.C. § 9621, because it meets the following requirements: 1) it is protective of human health and the environment; 2) it meets a level or standard of control of the hazardous substances, pollutants and contaminants that at least attains the legally applicable or relevant and appropriate requirements under federal and state laws (unless a statutory waiver is justified); 3) it is cost-effective; and 4) it utilizes permanent solutions and alternative treatment (or resource recovery) technologies to the maximum extent practicable.

In addition, Section 121 of CERCLA includes a preference for remedies that employ treatment that permanently and significantly reduce the volume, toxicity or mobility of hazardous substances as a principal element (or justify not satisfying the preference). Treatability studies will be conducted during the Remedial Design to determine the appropriate type and amount of stabilization amendments to treat the waste materials and meet the disposal standards of the receiving facility. The agents for stabilization may include fly ash, cement, soil, or other materials. The material removed during the remediation will be tested to comply with the applicable requirements.

This remedy will result in hazardous substances, pollutants, or contaminants remaining at the site above levels that will not allow for unlimited use and unrestricted exposure. Pursuant to Section 121(c) of CERCLA, statutory reviews will be conducted no less often than once every five years after the initiation of construction to ensure that the remedy is, or will be, protective of human health and environment. If justified by the review, additional remedial actions may be implemented to remove, treat, or contain the contaminants.

### Data Certification Checklist

The following information is included in the Decision Summary section of this ROD. Additional information can be found in the Administrative Record file for this site.

- A discussion of the nature and extent of contamination is included in the "Summary of Site Characteristics" section (Section 2.5).
- Chemicals of concern (COCs) and their respective concentrations (Sections 2.5)
- Baseline risks for human health and the environment represented by the COCs (Section 2.7)
- Cleanup levels established for COCs and the basis for these levels (Section 2.8)
- How source materials or highly toxic materials constituting Principal Threat Wastes are addressed (Section 2.12).
- Current and reasonably anticipated land use assumptions and current and potential future beneficial uses of groundwater used in the baseline risk assessment and the ROD (Section 2.6)
- Potential land and groundwater use that will be available at the site as a result of the Selected Remedy (Section 2.12)
- Estimated capital; annual operation and maintenance; and total present worth costs, discount rate, and the number of years over which the remedy cost estimates are projected (Section 2.12)
- Key factors that led to selecting the remedy (i.e., describe how the Selected Remedy provides the best balance of tradeoffs with respect to the balancing and modifying criteria, highlighting criteria key to the decision) (Section 2.10).

## 1.6 AUTHORIZING SIGNATURE

This ROD documents the Selected Remedy for the San Jacinto River Waste Pits Site. This remedy was selected by the EPA after consultation with the TCEQ.

By: \_\_\_\_\_ Date: \_\_\_\_\_

E. Scott Pruitt  
Administrator  
U.S. Environmental Protection Agency

**CONCURRENCE PAGE FOR RECORD OF DECISION****San Jacinto River Waste Pits Site**

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## **PART 2: THE DECISION SUMMARY**

This Decision Summary provides a description of the site-specific factors and analyses that led to the Selected Remedy. It includes background information, the nature and extent of contamination, assessment of human health and environmental risks posed by contamination, and identification and evaluation of remedial action alternatives for the site.

### **2.1 SITE NAME, LOCATION AND BRIEF DESCRIPTION**

The San Jacinto River Waste Pits Site is located in Harris County Texas (Figure 1) east of the City of Houston, between two unincorporated areas known as Channelview and Highlands. The National EPA Superfund Database Identification Number is TXN000606611. The EPA is the lead agency and the TCEQ is the support agency.

The site consists of a set of impoundments built in the mid-1960s for the disposal of solid and liquid pulp and paper mill wastes, and the surrounding areas containing sediments and soils impacted by waste materials disposed of in the impoundments. In 1965 and 1966, pulp and paper mill wastes (both solid and liquid) were transported by barge from the Champion Papers, Inc. paper mill in Pasadena, Texas, and deposited in the impoundments. The northern set of impoundments, approximately 14 acres in size, are located on a partially submerged 20-acre parcel on the western bank of the San Jacinto River, immediately north of the I-10 bridge over the San Jacinto River (Figure 2). Currently, approximately half of the northern 20-acre parcel, including the abandoned waste disposal ponds, is now submerged below the adjacent San Jacinto River's water surface. The southern impoundment, less than 20 acres in size, is located on a small peninsula that extends south of I-10.

The area receives an average of 54-inches of rain annually. The Site may be affected by tides, winds, waves, and currents resulting from extreme weather conditions such as strong storm winds, flooding, tornadoes, and hurricanes, which may cause a potential release or migration of dioxin and furan contaminated materials.

The primary hazardous substances documented at the Site are polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans. Physical changes at the site during the 1970s and 1980s, including regional subsidence of land in the area due to large scale groundwater extraction, resulted in partial submergence of the northern impoundments and exposure of the hazardous substances in the impoundments to surface water of the San Jacinto River.

A Time Critical Removal Action (TCRA) to address temporarily the hazardous substances associated with the impoundments north of I-10 was completed in July 2011. The TCRA included the installation of geotextile and geomembrane underlayments in certain areas and a temporary armored cap. The purpose of the temporary cap was to prevent hazardous substances from washing into the river during the site characterization and remedy selection process and to prevent the recreational use of the northern impoundments that had been occurring.

## 2.2 SITE HISTORY AND ENFORCEMENT ACTIVITIES

This section provides background information on past activities that have led to the current contamination at the Site, and federal and state investigations and cleanup actions conducted to date under CERCLA.

### 2.2.1 *Historical Activities*

In the 1960s, McGinnes Industrial Management Corporation transported liquid and solid pulp and paper mill wastes by barge from the Champion Papers, Inc. paper mill in Pasadena, Texas to impoundments located north of I-10, adjacent to the San Jacinto River, where the waste was disposed of. Champion Papers, Inc. business records indicate the paper mill produced pulp and paper using chlorine as a bleaching agent (EPA 2009). The pulp bleaching process forms dioxins and furans as a by-product. Historical activities for each area are discussed below.

#### **Northern Impoundments**

Impoundments were built by constructing berms prior to 1965 within the estuarine marsh to the west of the main channel of the San Jacinto River, just north of what was then Texas State Highway 73 and is now I-10. The impoundments were divided by a central berm running lengthwise (north to south) through the middle, and were connected with a drain line to allow flow of excess water (including rain water) from the impoundment located to the west of the central berm into the impoundment located to the east of the central berm. The excess water collected in the impoundment located to the east of the central berm was supposed to be pumped back into barges and taken off-site (Anchor and Integral 2010).

On December 27, 1965, the Harris County Health Department observed pumping of liquid waste out of one of the ponds directly into the San Jacinto River (EPA 2009). The Harris County Health Department instructed McGinnes Industrial Management Corporation and Champion Papers by letter to stop discharging to the San Jacinto River and demanded that the levees surrounding the impoundments be repaired (EPA 2009). An internal memo, dated 30 December 30, 1965, from Champion Papers, Inc. confirmed water seepage along the levees and that portions of the levees required reinforcement (EPA 2009).

In May 1966, the Texas Department of Health investigated Champion Papers, Inc. waste disposal practices. Seepage was noted on the western waste pond and deteriorating levees on the eastern waste pond. The Texas Department of Health also noted that storm events had the potential to cover the disposal area with water and wash out the levees.

On July 29, 1966, the Texas Water Pollution Control Board granted McGinnes Industrial Management Corporation permission to release a combination of stabilized waste water and rain water from waste ponds into the San Jacinto River. It was also noted that the waste ponds would no longer be used for the storage of waste material (EPA 2009).

Physical changes at the site in the 1970s and 1980s, including regional subsidence of land in the area due to large scale groundwater extraction and sand mining within the river and marsh to the

west of the northern impoundments, have resulted in partial submergence of the impoundments north of I-10 and exposure of the contents of the impoundments to surface waters. During the mid- to late 1990s, third-party dredging likely occurred in the vicinity of the perimeter berm at the northwest corner of the northern impoundments.

A release of the hazardous substances from the northern impoundments was identified through site assessment activities conducted by EPA and TCEQ in 2006. Site assessment activities included surface water and sediment sampling for the presence of dioxins and furans. People and animals coming on to the site could be exposed to these contaminants through ingestion, skin contact and inhalation pathways. Further, during a site visit by EPA conducted on March 1, 2010, releases of hazardous substances were observed entering the San Jacinto River from the northern impoundments.

A temporary cap constructed over the northern waste pits in 2010 and 2011 (pursuant to an Administrative Settlement Agreement and Order on Consent for Removal Action) experienced repeated damage and repairs during the six years since construction. A discussion of this history of repeated damage is included below under the section titled "Administrative Settlement Agreement and Order on Consent for Removal Action".

### **Southern Peninsula**

The peninsula south of I-10 has a complicated history that includes evidence of disposal of paper mill waste, disposal of anthropogenic waste, and subsequent industrial activities. An impoundment located on the southern peninsula and used for disposal of paper mill waste was likely constructed sometime between 1962 and 1964, based on evidence of berms visible in historical photos. The oldest aerial photo that contains evidence of the construction of berms is from 1964. The berms that seem to define an impoundment appear to have been formed in the same manner as the impoundments north of I-10, with sidecast from trenching providing the berms of the impoundment that ultimately contained the waste. The extent of the area potentially affected by waste disposal in the southern impoundment is uncertain, but is most likely within the area enclosed by the berms.

Disposal of paper mill waste from Champion Papers, Inc. was performed by Ole Peterson Construction Co., Inc. at the southern impoundment. An April 29, 1965 agreement between Champion Papers and Ole Peterson Construction provides for the removal and barge transportation of pulp and paper mill waste from the Champion plant for disposal; this agreement was assigned to McGinnes Industrial Maintenance Corporation in September 1965. A Texas State Department of Health interoffice memorandum dated May 6, 1966, states that disposal of Champion waste at the site began in June 1965 by Ole Peterson, with McGinnes taking over the operation in September 1965. The memorandum describes the older site for disposal as being on the south side of Highway 73 (now Interstate 10) and consisting of a pond between 15 and 20 acres. The memorandum states that the older pond on the south side was used prior to McGinnes taking over the waste disposal activities.

The impoundment on the southern peninsula was also used for dumping of various anthropogenic wastes (e.g., wood, plastic sheeting, paint chips, ceramic shards) since at least the

early 1970s. Aerial photographs and anecdotal information indicate that the impoundment berms were still visible in 1972, when the current landowner's family purchased the property on which they were located. Soon after 1972, the impoundment berms were graded down. The entire peninsula south of I-10 was subject to continuous and significant modification from the early 1970s through the 1980s. From 1985 to 1998, Southwest Shipyards leased a portion of the western shoreline of the southern peninsula, immediately to the south of the present-day location of Glendale Boat Works operations on property owned by New Lost River, LLC. This area includes the shoreline area that appears to be flooded in the 1973 aerial photograph and that was filled in by 1984. Southwest Shipyards conducted sandblasting and painting of barges in this area, and spent blast sand was stockpiled along an unknown portion of the shoreline. Aerial photographs provide evidence of deposition and transport of large volumes of material, significant changes in the form of the landscape, and continuous physical change from at least 1972 to the present.

### **2.2.2 *Pre-CERCLA Investigations***

Between 1993 and 1995, the City of Houston conducted a toxicity study of the Houston Ship Channel that included the San Jacinto River in accordance with a Consent Decree between EPA and the City of Houston. Sediment, fish, and crab samples were collected in August 1993 and May 1994. Sediment, fish, and crab samples collected near the site indicated elevated dioxin and furan levels (ENSR Consulting and Engineering and Espey, Huston and Associates 1995). Between 2002 and 2004, the TCEQ conducted a study of total maximum daily loads (TMDLs) for dioxins and furans in the Houston Ship Channel (University of Houston, Parsons Engineering, and PBS&J 2004). Sediment, fish, and crab samples were collected in the summer of 2002, fall 2002, spring 2003, and spring 2004. The data indicated the continued presence of elevated dioxin and furan contamination in the San Jacinto River surrounding the site. Results indicated that the human health-based standard was exceeded by 97 percent of fish samples and 95 percent of crab samples (Anchor and Integral 2010).

In April 2005, the Texas Parks and Wildlife Department (TPWD) sent a letter notifying TCEQ of the existence of former waste pits in a sandbar in the San Jacinto River north of I-10. The letter included discussion of anecdotal evidence, data collected during the Houston Ship Channel Toxicity Study (ENSR Consulting and Engineering and Espey, Huston and Associates 1995) and TMDL study (University of Houston, Parsons Engineering, and PBS&J 2004), documentation of U.S. Army Corps of Engineers (USACE) dredge and fill permits in the area, and requested that TCEQ further investigate the site (TPWD 2005).

A preliminary assessment and screening site inspection was conducted between 2005 and 2006 to determine if the site was eligible for proposal to the National Priorities List (NPL) (TCEQ 2005). Site reconnaissance identified the surface water pathway as the primary pathway of concern. Seventeen sediment samples were collected from the San Jacinto River to evaluate background, potential source areas, and possible releases. Samples were analyzed for semivolatile organic compounds (SVOCs), pesticides, PCBs, dioxins and furans, and metals. Sediment sample results indicated elevated concentrations of dioxin congeners. The former surface impoundments were identified as the source of hazardous substances at the site (TCEQ 2006).

The Hazard Ranking System is the principal mechanism the EPA uses to place sites on the NPL. The Hazard Ranking System Documentation Record for the site was published by TCEQ in 2007. The site score was 50 because of components of the surface water overland/flood migration pathway (TCEQ 2007). Any site scoring 28.5 or greater is eligible for the NPL (EPA 1992).

### ***2.2.3 National Priorities List***

The site was proposed for listing on the NPL List on September 19, 2007 (72 FR 53509), and was placed on the list effective April 18, 2008 (73 FR 14719).

### ***2.2.4 Unilateral Administrative Order for Remedial Investigation/Feasibility Study***

On July 17, 2009, EPA sent Special Notice Letters to the International Paper Company, Inc. and McGinnes Industrial Management Corporation offering them an opportunity to negotiate and enter into an Administrative Order on Consent covering the performance of a Remedial Investigation (RI)/Feasibility Study (FS) for the site. EPA did not receive a Good Faith Offer from either company to begin negotiations for a RI/FS for the site (EPA 2009).

On November 20, 2009, EPA issued Unilateral Administrative Order (UAO), CERCLA Docket No. 06-03-10, to the International Paper Company, Inc. and McGinnes Industrial Management Corporation. The International Paper Company, Inc. is the successor to Champion Papers, Inc., which arranged for the disposal or treatment of materials containing hazardous substances that were disposed of at the site (EPA 2009). McGinnes Industrial Maintenance Corporation operated the waste disposal facility at the time of disposal of hazardous substances at the site (EPA 2009). The UAO directed International Paper Company, Inc. and McGinnes Industrial Management Corporation to conduct a RI/FS in accordance with provisions of the order, CERCLA, the NCP, and EPA guidance. EPA also required the investigation of the impoundment located south of I-10 because historical documents indicate that waste disposal activities occurred in this area (Integral and Anchor 2013a).

### ***2.2.5 Administrative Settlement Agreement and Order on Consent for Removal Action***

The EPA's April 2, 2010 Request for a Time-Critical Removal Action at the San Jacinto River Waste Pits Site documented the hazardous conditions at the San Jacinto River Waste Pits prior to the removal action, finding that should a removal action be delayed, the potential threats to human health and the environment would increase; a substantial amount of dibenzo-p-dioxins and polychlorinated dibenzofurans would continue to be released and spread into the San Jacinto River; and unrestricted access to the site would continue to threaten nearby populations. Following the April 2010 Action Memorandum, McGinnes Industrial Maintenance Corporation and International Paper voluntarily entered into the Administrative Settlement Agreement and Order on Consent for Removal Action, CERCLA Docket No. 06-12-10, dated May 11, 2010. The administrative agreement provided for the performance of the site removal action and the reimbursement of EPA oversight costs.

Pursuant to the April 2010 Action Memo and the administrative order, the PRPs prepared and submitted a technical memorandum to evaluate all removal option alternatives for the design and construction of a physical protective barrier surrounding the waste ponds in order to temporarily address the releases or threat of release from the Site. Based on the analysis of alternatives in the PRPs' technical memorandum, the EPA Decision Document for the Time-Critical Removal Action, dated July 28, 2010, selected the cap currently in place at the Site to temporarily abate the releases and threats of releases of dioxin until a permanent remedy could be evaluated and selected. The July 2010 Action Memorandum required that the time critical removal action stabilize the impoundments to withstand forces sustained by the river, including a cover design that considered storm events with a return period of 100 years (Figure 9).

#### 2.2.1.1 *Northern Waste Pits Cap*

Elements of the selected TCRA included construction of a perimeter fence on the uplands to prevent unauthorized access, placement of warning signs around the perimeter of the impoundments and on the perimeter fence, design and implementation of an operations, monitoring, and maintenance plan, and installation of the following items as part of the temporary cap:

- A stabilizing geotextile underlayment over the eastern and western cells;
- An impervious geomembrane underlayment in the western cell;
- A granular cover over the northwestern area of the western cell;
- A granular cover above the geotextile and geomembrane in the western cell; and
- A granular cover above the geotextile in the eastern cell.

Additionally, the western cell received treatment through stabilization and solidification of approximately 6,000 cy of material in the upper 3 feet of paper mill waste material.

From December 2010 through July 2011, TCRA construction activities were completed at the site. On 1 August 2011, EPA conducted a final site walk through accompanied by International Paper Company, Inc., McGinnes Industrial Management Corporation, Anchor, and USA Environment, LP. The *Revised Final Removal Action Completion Report*, which documents the TCRA construction activities, was completed in May 2012 (EPA 2012).

The *Operations, Monitoring, and Maintenance Plan, Time-Critical Removal Action, San Jacinto River Waste Pits Superfund Site* identifies continuing obligations, including monitoring and maintenance, with respect to the TCRA (Anchor 2011). Inspections of fencing, signage, and the protective armored cap are required quarterly for the first 2 years following completion of the TCRA (January 2012 through December 2013), semiannually for years three to five (April 2014 through October 2016), and annually starting at year six (July 2017 and beyond). However, the current inspection frequency is quarterly in response to the repeated instances of cap repair required following completion of the cap. Inspections of the armored cap are also required following the first 25-year flow event and after each 100-year flow event. TCRA inspection events include:

- Visual inspection of the security fence and signage surrounding the site;
- Visual inspection of the armored cap located above the water surface;

- Visual observation that waste materials are not actively eroded into the river;
- Collection of topographic survey data for the portions of the armored cap that are located above the water surface or at a water depth too shallow to access by boat;
- Collection of bathymetric survey data for the portions of the armored cap that are below the water surface and accessible by boat; and
- Manual probing of armored cap thickness at areas identified by the topographic or bathymetry surveys as more than 6 inches lower in elevation than during the prior survey.

If the visual inspection identifies a breach in the security fence or damaged or missing signs, repairs or replacement will be made as soon as practicable, but not to exceed two weeks following the inspection. Repair activities to the armored cap are required if (1) the thickness of the armored cap is less than 6 inches than the thickness specified by the TCRA design over a contiguous area greater than 30 feet by 30 feet in size, (2) the armored cap has any area of complete absence, or (3) visual observation indicates that waste materials are being actively eroded into the river. Inspection and repair reports, as needed, are submitted to EPA.

Since its completion in July 2011, the temporary armored cap has generally isolated and contained impacted material, with the known exceptions noted below. The following events have been documented since the time of armored cap installation:

- In July 2012, an area along the western berm slope was noted to have areas where cap armor materials had moved down the slope, uncovering an area of the geotextile layer (approximately 200 square feet, or 0.03 percent of the armored cap footprint). There was no exposure of underlying materials or release of hazardous substances associated with this temporary condition. Maintenance measures were completed that involved grading specific locations to an overall flatter condition by placing additional armor rock over the cap surface in those locations.
- In January 2013, five areas in the eastern cell of the cap with less than the required armor cover thickness and/or exposed geotextile were identified. In one of those areas there was a need for placement of geotextile fabric in addition to armor stone (Figure 3). The cause of these areas of deficient cap cover is unknown. These areas were repaired in January 2013 with the addition of additional stone and geotextile.
- In response to USACE recommendations following their post-construction evaluation (USACE 2013) of the armored cap, additional cap enhancement work was completed in January 2014. In order to address the factor of safety, slope of the face of the berm, and uniformity of cap material, additional stone was placed on the armored cap.
- On December 9 and 10, 2015, EPA performed an underwater inspection that identified an area of missing armor cover resulting in exposure of the underlying paper mill waste material to the San Jacinto River. The damaged area, approximately 400 to 500 square-feet, was located on the northwestern section of the armored cap where no geotextile was installed (Figure 4). Armored rock cover was intermittent with gaps where the rock had sunk into the paper mill waste leaving the waste material openly exposed to the San Jacinto River. This failure appeared to be caused by a bearing capacity failure from a poor filter layer and soft underlying waste materials. Sediment sampling completed in

December 2015 identified dioxins and furans in the exposed sediment as high as 43,700 ng/kg TEQ. Repair activities to place geotextile and additional rock cover in the damaged area were completed on January 4, 2016.

- On February 2016, during an extremely low tide, a visual inspection of the cap was performed. A large majority of the eastern cell was exposed during this low tide event. Five small areas (approximately 1 foot by 3 feet at the largest areas) of exposed geotextile with no rock cover were observed in the central part of the eastern cell where the cap should have had a 1-foot thickness minimum. The cause of these deficient rock areas is unknown. During March 2016, probing of the entire eastern cell of the cap to check thickness was completed and identified numerous additional areas of deficient armor cover thickness and/or exposed geotextile from apparent shifting or movement of the armor cap (Figure 5). Rock was added to all of these areas in the eastern cell in March 2016 to achieve a minimum thickness of 1 foot.
- Flooding in the Spring of 2016 resulted in several areas of riverbed erosion/scour adjacent to the eastern edge of the armored cap. The erosion into the riverbed reached a depth of approximately 8-feet (Figure 6). Following a review by the U.S. Army Corps of Engineers, approximately 1300 tons of rock were delivered and placed to stabilize the edge of the cap and prevent any further erosion that could undermine the cap.
- Flooding in September 2017 resulting from Hurricane Harvey eroded armor rock from the cap. Armor stone as well as the underlying geotextile was completely eroded from portions of the southern berms (Figure 7). In addition, approximately 36 areas within the cap ranging in size from 1-square foot to 50-square feet were found with either a reduced cap thickness, intermittent rock cover, or no cap rock present (Figure 8). These areas were located in the eastern cell, the western cell, and the northwest part of the waste pits. In some areas the underlying geotextile was exposed, and in other areas the underlying soft material was exposed to the San Jacinto River. This soft material was, or could have been, paper mill waste. Samples of the exposed soft material were collected by the EPA Dive Team, however, the validated results are not available at this time. Approximately 1000-tons of rock were delivered to repair these 36 areas of damaged cap.
- Previous samples (collected December 2015) from the surface of the northwest part of the waste pits, where there is no geotextile present now, showed dioxin/furan ranging from 383 ng/kg TEQ to over 43,000 ng/kg TEQ. Because the northwest area does not have a geotextile liner, material containing up to 43,000 ng/kg TEQ dioxin/furan may have been exposed to the San Jacinto River during Hurricane Harvey.
- The flooding as a result of Hurricane Harvey also eroded a section of the riverbed immediately adjacent to the east side of the cap. This erosion next to the cap is a concern because it may have undercut and caused a loss of part of the cap. The exact dimensions and depth of the erosion area are not available at this time. A plan to stabilize the cap in this area is currently being prepared by the PRPs for EPA approval.

The EPA notes that the recent flooding from Hurricane Harvey resulted in a 500-year flood in the San Jacinto River as indicated by the Harris County Flood Warning System. This flooding resulted from excessive rainfall associated with the hurricane and did not include the erosion effects of hurricane wind driven waves, which would be expected to increase the amount of cap damage that occurred.

The above history of continuing damage to the cap, the exposure of high concentration (43,000 ng/kg TEQ) dioxin and furan wastes to the environment, the instances of erosion of the riverbed next to the cap, and the need for repeated repairs illustrate the lack of effectiveness that has been documented for the relatively short time, 6 years, since the cap was completed. The repairs to the temporary cap over the last six years have not been routine and within the scope of what was contemplated at the time the cap was completed in 2011. The 2011 Operations, Maintenance, and Monitoring Plan provided that inspections of the cap would be “performed quarterly for the first two years following completion of the TCRA construction, semiannually from years three to five, and annually starting at year six,” with provision for additional inspections after 25-year or 100-year flow events (*Operations, Monitoring, and Maintenance Plan, San Jacinto River Waste Pits Superfund Site, October 2011, Section 2.1, p. 5*). This provision envisions that the cap would require significantly less inspection and resulting maintenance after its first two years of operations, which has not in fact been the case. While cap inspections were at one point decreased from quarterly to semiannually, in February 2016 the frequency of the inspections had to be increased again to every quarter, due to the issues discovered by the EPA dive team in December 2015 as part of a sampling effort. The expectation that extensive maintenance to the cap would be limited to its first two years is also found in the cost estimates provided by Anchor QEA in its draft of the Feasibility Study, as resubmitted in April 2014. The cost for “Armored Cap Maintenance” was assumed only as “\$100,000 cap maintenance in Year 1 and 2.” (*Draft Final Interim Feasibility Study, March 2014, Appendix C: Remedial Alternative Cost Development, Table 1*). The total estimated costs for cap maintenance as a net present value for Alternative 2N (the TCRA cap) and 3N (an enhanced cap) were both estimated as a net present value as only \$181,000. The significant repairs in December 2015 and early 2016, the repair of the area with scour in November 2016, and the current efforts to repair the cap in 2017 demonstrate that the maintenance of the cap has not been routine and expected, but instead indicates an ongoing problem.

Further, the impacts of a strong hurricane with its storm surge and wind driven waves has not yet occurred at the Site; however, one or more strong hurricanes are likely over the long term that the dioxin, a persistent waste, would remain toxic. Finally, modeling conducted by the U.S. Army Corps of engineers has determined that a Category 2 hurricane in conjunction with flooding would result in erosion over most of a cap that is significantly upgraded over the current cap. Stronger Category 3, 4, or 5 hurricanes are possible and may have even greater impacts to the cap.

## 2.3 COMMUNITY PARTICIPATION

This section of the ROD describes the EPA’s community involvement and participation activities. EPA has been actively engaged with stakeholders and has encouraged community participation during EPA’s remedial and removal activities. These community participation

activities during the remedy selection process meet the public participation requirements in CERCLA 300.430(f)(3) and the NCP.

### **2.3.1 *Community Involvement Plan***

The Community Involvement Plan is central to Superfund community involvement. It specifies the outreach activities that the EPA undertakes to address community concerns and expectations. The Community Involvement Plan included background information on the community, community issues and concerns, community involvement activities, communication strategy, official contact list, and local media contacts. The Community Involvement Plan was last updated in June 2016.

### **2.3.2 *Community Meetings and Fact Sheets***

The EPA and TCEQ have conducted community meetings during the course of the Superfund process. In addition, factsheets detailing site activities have been published periodically since the site was listed on the NPL and are available in the Administrative Record.

The Proposed Plan presented the EPA's rationale for the Preferred Remedy. A public comment period for the Proposed Plan was held from September 29, 2016, until January 12, 2017. The public comment period was originally slated to last 60-days until November 28, 2016. However, in response to requests for an extension, the public comment period was extended an additional 45 days until January 12, 2017. As part of the public comment period, a community meeting was held at the Highlands Community Center in Highlands, Texas, on October 20, 2016. A public notice of the community meeting and public comment period was published in the Baytown Sun newspaper on September 30, 2016, and in the Houston Chronicle newspaper on October 1, 2016. Additionally, a fact sheet announcing the comment period and meeting was mailed to the contacts included on the Site's mailing list.

At the community meeting, representatives from the EPA provided a presentation on the Proposed Plan and received questions about EPA's Preferred Alternative. Representatives from the TCEQ were also present at the meeting. Oral and written comments were accepted at the meeting and a court reporter transcribed the discussions held during the meeting. This transcript is included in the Administrative Record file for the site. The EPA's responses to the comments received during the public comment period are included in "Part 3: Responsiveness Summary."

EPA, in cooperation with elected officials and state, county, and local agencies, has been providing community outreach and public participation for the site since it was added to the National Priorities List in 2008. EPA's community involvement began with a community meeting in 2010 to provide the public with information regarding the site and share information on the Superfund process, the next steps, and how the community could get involved in the process.

In early outreach efforts, some community members voiced concern that they were not receiving sufficient information from EPA. As a result, EPA increased its outreach and community involvement efforts. EPA deemed the site a Community Engagement Initiative Site and in 2010 performed additional outreach planning, such as informational meetings and mail outs to a large

site mailing list. Later that year, EPA initiated a Community Advisory Group for the site known as the Community Awareness Committee. The 16-member group, which includes representatives from the community as well as state agencies, local governments, environmental organizations, and the PRPs, began a series of quarterly meetings at the Harris County Attorney's Office.

Other outreach and community involvement efforts include coordinated outreach with the Texas Department of State Health Services to survey nearby communities (door to door) to better understand their health concerns and to provide site information and an Environmental Justice survey. In 2012, EPA provided a Technical Assistance Grant to the Galveston Bay Foundation to hire a technical advisor to provide assistance. In addition, a number of local internet websites are being utilized to keep area citizens updated on site events.

EPA will continue to provide community meetings, open houses, elected officials briefings, media interviews, public notices, and fact sheets to inform the public and keep residents updated on all site developments that affect cleanup actions.

### **2.3.3 Information Repositories**

The Administrative Record file is available for review at:

**Highlands Public Library**

Stratford Branch Library  
509 Stratford Street  
Highlands, Texas 77562  
(281) 426-3521

**U.S. Environmental Protection Agency, Region 6**

7<sup>th</sup> Floor Reception Area  
1445 Ross Avenue, Suite 12D13  
Dallas, Texas 75202-2733

**Texas Commission on Environmental Quality**

Building E, Records Management  
12100 Park 35 Circle  
Austin, Texas 78753  
(800) 633-9363

## **2.4 SCOPE AND ROLE OF RESPONSE ACTION**

The NCP, 40 CFR Section 300.5, defines an operable unit as a discrete action that comprises an incremental step toward comprehensively addressing a site's contamination problems. The cleanup of a site may be divided into one or more operable units, depending on the complexity of the problems associated with the site. The EPA has chosen to address the site as a whole without division into operable units. The selected remedy addresses the contaminated environmental media at the Site with the primary objectives of preventing human exposure to contaminants, and preventing or minimizing further migration of contaminants. The remedial action objectives (RAOs) are described in more detail in Section 2.8.

## 2.5 SUMMARY OF SITE CHARACTERISTICS

This section presents a brief, comprehensive overview of the site. This section has been divided into three subsections that include physical characteristics, conceptual site model, and the nature and extent of contamination.

### 2.5.1 *Physical Characteristics*

This subsection provides a summary of site surface features, climate, surface water hydrology, geology, ecology, and habitats. Detailed information on these topics can be found in the Administrative Record, including the *Remedial Investigation Report, San Jacinto River Waste Pits Superfund Site* (Integral and Anchor 2013a).

#### **Surface Features**

The site is located in the estuarine portion of the lower San Jacinto River where the river begins to transition from a fluvial system to a deltaic plain. The northern impoundments cover an area approximately 15.7 acres in size including the berms. Pre-TCRA ground surface elevations ranged from 0 feet above mean sea level (MSL) at the shoreline, to nearly 10 feet above MSL. South of I-10, ground surface elevations range from 0 feet above MSL at the shoreline to nearly 13 feet above MSL. Both areas are generally flat with very little noticeable topographic relief. Relief south of I-10 is the likely result of building foundations and leftover cut material from grading.

#### **Climate**

The climate along the Gulf Coast of Texas and the area surrounding Houston is humid subtropical. The average annual precipitation is 54 inches. The warmest month is July, with an average temperature of 85 degrees Fahrenheit (°F), and the coldest month is January, with an average temperature of 54°F. During the spring season, large thunderstorms are common and are capable of producing tornados. The transition to the summer months is characterized by mild temperatures, but relative humidity of up to 90 percent results in a higher heat index.

The monthly average precipitation varies from approximately 2.5 inches in February to over 7 inches in June. It is not uncommon to have precipitation events that exceed 2 inches per day, and rain events bringing 10 inches of precipitation or higher in a day occur on a decadal scale. These types of precipitation events produce wide variations in the volume of discharge into and out of the San Jacinto River and may significantly affect variations in flow velocities, sediment transport, and suspended sediment loads.

The Texas Gulf coast was recently struck by Hurricane Harvey. While Hurricane Harvey did not make landfall in the Houston area, the hurricane pushed moisture inland, which stalled over Houston causing historic rainfall, runoff, and flooding. The highest rainfall amount totaled 48.20 inches at a rain gauge on Clear Creek and I-45 near Houston Texas. It was the highest rainfall amount in a single storm for any place in the continental United States (NOAA, 2017).

## Surface Water Hydrology

The frequency of hurricanes along any 50-mile segment of the Texas coast is about 1 every 6 years; the annual average occurrence of a tropical storm or hurricane is about 1 per year (Roth, 1997). Between 1851 and 2004, 25 hurricanes have made landfall along the north Texas Gulf Coast, seven of which were major (Category 3 to 5) storms. Tropical Storm Allison, which hit the Texas Gulf Coast in June 2001, resulted in 5-day and 24-hour rainfall totals of 20 and 13 inches, respectively, in the Houston area, resulting in significant flooding. More recently, Hurricane Rita made landfall in September 2005 as a Category 3 storm with winds at 115 miles per hour. The storm surge caused extensive damage along the Louisiana and extreme southeastern Texas coasts. In September 2008, the eye of Hurricane Ike made landfall at the east end of Galveston Island. Ike made its landfall as a strong Category 2 hurricane, with Category 5 equivalent storm surge, and hurricane-force winds that extended 120 miles from the storm's center. Climate models (Knutson and others, 2010) predict an increase in the intensity of tropical cyclones and hurricanes in the Gulf, meaning greater risk of flooding and storm surges over the long time frame that the dioxin waste at the Site would remain hazardous.

The San Jacinto River Waste Pits Site is located in a Federal Emergency Management Agency (FEMA) designated "VE" Floodway Zone, meaning that it is prone to inundation by the 1 percent annual chance flood event with additional hazards due to storm induced waves (Brody and others, 2014). As noted in "A Flood Risk Assessment of the San Jacinto River Waste Pit Superfund Site" (Brody and others, 2014):

"National Oceanic and Atmospheric Administration (NOAA) surge models for a category 3 storm striking Galveston Bay during high tide show surge levels at the waste pit site reaching 23 feet. A category 5 storm hitting the Bay during similar conditions would produce a storm tide of up to 33 feet. Keim, Muller & Stone, (2007) also derived an average return period of 3 years for tropical storms, 8 years for all Hurricanes, and 26 years for hurricanes category 3-5 for Galveston, Texas. Researchers at NOAA's National Hurricane Center corroborate this estimate, predicting the return period for a major hurricane (category 3) striking Galveston Bay at 25 years".

The river in the vicinity of the northern impoundments is affected by diurnal tides, with a typical tidal range of about 2 feet. Tidal range varies over a 14-day cycle, with neap and spring tide conditions corresponding to minimum and maximum tidal ranges, respectively. A tidal river is an inherently more dynamic environment than would be a more stable inland location not subject to currents, changes in stage, and the more focused effects due to flooding, storm surges, and hurricanes to which the current location is subject.

Salinity in the vicinity of the site ranges between 10 and 20 parts per trillion during low to moderate flow conditions in the river. During floods, salinity values will approach freshwater conditions.

Flow rates in the San Jacinto River at the site are partially controlled by the Lake Houston dam, which is located about 16 river miles upstream of the northern impoundments. The average flow in the river is 2,200 cubic feet per second (cfs). Floods in the river occur primarily during tropical storms (e.g., hurricanes) or intense thunder-storms. Extreme flood events have flow rates

of 200,000 cfs or greater. Floods can cause water surface elevations to increase by 10 to 20 feet or more (relative to average flow conditions).

The San Jacinto River has experienced actual short-term alterations in the past. The most substantial and dramatic changes to river or estuarine environments occur as a result of extreme events, the effects of which are more difficult to predict. For example, in October 1994, heavy rainfall occurred in southeast Texas resulting in the San Jacinto River Basin receiving 15 to 20 inches of rain during a week-long period. One of the largest measurements of stream flow ever obtained in Texas, 356,000 cubic feet per second (cfs), was made on the San Jacinto River near Sheldon on October 19, 1994, at a stage of 27 feet. During the measurement, velocities of water that exceeded 15 feet per second (about 10 miles per hour) were observed. The 100-year flood, which is defined as the peak stream flow having a one percent chance of being equaled or exceeded in any given year, was exceeded at 18 of 43 stations monitoring the area. For those stations where the 100-year-flood was exceeded, the flood was from 1.1 to 2.9 times the 100 year-flood. The flood waters scoured the riverbed and banks, destabilized roads and bridges, and inundated area homes.” (NTSB, 1996). The railroad and highway roadbeds and bridges sustained major damage during the 1994 flood (USGS, 1995).

The 1994 flooding caused major soil erosion and created water channels outside of the San Jacinto River bed. This flooding caused eight pipelines to rupture and 29 others were undermined at river crossings and in new channels created in the flood plain outside of the San Jacinto River boundaries. The largest new channel was cut through the Banana Bend oxbow just west of the Rio Villa Park subdivision, about 2½ miles northwest of the Site. This new channel was approximately 510-feet wide and 15-feet deep. A second major channel cut through Banana Bend just north of the channel through the oxbow. Both of these new channels were cut through areas where sand mining had been done before, as is the case in the vicinity of the Site. Sonar tests in a 130-foot section south of the I-10 Bridge located adjacent to the Site found about 10 to 12-feet of erosion from the bottom of the river bed. Two other recorded floods in the San Jacinto River actually exceeded the 1994 flood, including during 1929 (32.90-feet) and during 1940 (31.50-feet).

More recently, river bed scour, approximately 8-feet deep, was identified in 2016 adjacent to the temporary cap. Additional river bed scour occurred in 2017 during the flooding associated with Hurricane Harvey, immediately adjacent to the east side of the cap, although the magnitude of this scour is unknown at this time. These scour events point to the potential for change in the San Jacinto River bed and the dynamic nature of the river.

The San Jacinto Superfund Site was effected by the historic flooding caused by Hurricane Harvey, but the area didn't receive high winds or storm surge typical of a hurricane. If a hurricane hit directly in this area in the future, one would expect to have waves driven by high winds, flooding, and storm surge adding additional energy to the river system, which could cause additional erosion to the stream bed and flood plain in the area.

The USGS performed a review of the geomorphic characteristics of the San Jacinto River based on review of historic documents in response to comments submitted during the public comment period. This review noted that geomorphic evaluations based on the behavior of upland river systems may not accurately simulate scenarios in a river downstream of a reservoir and in

immediate contact with a tidal estuary, as is the case in the vicinity of the site. Also, the review stated that what cannot be accurately predicted are the conditions that the impoundments and channels at the Site will be subjected to, given the need to secure the impoundments for the long term that the dioxin would remain hazardous. A variety of models could be used to test potential effects to specific areas of the stream channel or impoundments with the application of specific stress conditions. However, the complex way in which the effects of these individual stresses interact and propagate through the river system in the area of the impoundments cannot be reliably simulated with existing models. Several models suggested as candidates by commenters on the Proposed Plan (HEC RAS 5.0 with BSTEM and the morphodynamic meander models of Langendoen and others (2015 and 2016)) were designed to model upland river systems. Specifically, classification schemes such as those by Lagasse and others (2004), which can be used to establish channel stability, were designed to classify upland river systems. The San Jacinto River in this reach is downstream of a dam and is part of a coastal-plain estuary. As such, there are additional forces acting on the river as mentioned before, such as downriver releases from the dam and upriver/onshore forces such as hurricanes and storm surges, which can affect the morphology of the area in ways not accounted for in an upland river classification scheme.

The USGS concluded that the need to simulate scenarios in a river downstream of a reservoir and in immediate contact with a tidal estuary introduces factors into the analysis not accounted for in these models. The USGS also stated that accurately evaluating the uncertainty of model predictions would be problematic given uncertainties in long-term future conditions for the San Jacinto River.

Hayter and others (2016) refer to “the dynamic nature of the flow regime in the San Jacinto River estuary” in their assessment of the hydrology and hydrodynamics of the river, referencing the location of the Waste Pits within the FEMA designated 100-year floodplain, susceptibility to flooding from storm surges, and vulnerability of the Site due to sea level rise. While it is possible to evaluate a river as dynamic in terms of its tendency towards lateral channel migration and channel avulsion, a “dynamic system” also could be considered a system subject to a wide range of flooding and storm surges, and this type of activity will continue irrespective of the additional impacts of subsidence or dredging that might occur in the area. Warner and Tissot (2012) conservatively estimate a sea level rise at Galveston Bay of 2.1 feet over the 21st Century, and continuously increasing risks of flooding from storm surges as the century progresses. By this definition, the river should be considered dynamic, especially in comparison to low energy river environments, protected harbors and low flow streams, with the river likely becoming increasingly more dynamic over time.

The San Jacinto River has been prone to severe flooding with major floods occurring prior to the 1994 flood in 1907, 1929, 1932, 1935, 1940, 1941, 1942, 1943, 1945, 1946, 1949, 1950, 1959, 1960, 1961, 1972, and 1978 (NTSB, 1996). The actual history of the San Jacinto River and the uncertain impacts of future storms are sufficient to raise concerns about the stability of structures constructed in the river over the long time frame that the dioxin waste would remain hazardous.

### **Regional Geology and Hydrogeology**

Sediments of the Texas Gulf Coast are generally Cenozoic fluvial-deltaic to shallow-marine deposits of a coastal plain environment (U.S. Geological Society [USGS] 2002). Sea-level

transgression-regression cycles and natural basin subsidence have produced beds of clay, silt, sand, and gravel that gently dip southeast towards the Gulf of Mexico. This complex depositional process created both a continental assemblage of sediments that now make up the aquifers within the area and a marine sequence of sediments that contains clay layers and confining units. This process resulted in a regional aquifer system with a high degree of heterogeneity in both lateral and vertical extent (USGS 2002) commonly referred to as the Gulf Coast Aquifer System (Texas Natural Resource Conservation Commission 1999).

The Gulf Coast Aquifer System is located along the coast of the Gulf of Mexico and has been divided into four units: the Chicot, Evangeline, and Jasper aquifers, and the Burkeville confining unit. The Site is above the Evangeline (deeper) and Chicot (shallower) aquifers. Groundwater elevation maps for the Evangeline and Chicot aquifers show that regional groundwater flow is directed approximately southeast towards the Gulf of Mexico (USGS 2002). On a localized net flow basis, shallow groundwater may discharge to the San Jacinto River, providing a portion of base flow. Under high tide and river flow conditions, a temporary gradient reversal may cause the San Jacinto River to temporarily recharge the shallow alluvium adjacent to the river.

The Chicot Aquifer is used as a drinking water source within the greater Houston area, but water used from this source is pumped from wells screened far below the Beaumont Formation, a confining clay. Although there are some privately owned upper Chicot Aquifer wells near the Site, the infiltration of surface waters or shallow groundwater would likely be prevented in most cases by the thick sequence of the clay and silt deposits of the Beaumont Formation, effectively isolating the lower portion of the Chicot Aquifer from shallower groundwater and surface water in the vicinity (USGS 2002).

### **Local Geology and Hydrogeology**

At the site, the surface and underlying local soils include Holocene alluvial deposits and the Beaumont Formation, which is the youngest and uppermost of the series of coast-parallel Pleistocene deposits that make up the Gulf Coast Aquifer System. The soils of the Beaumont Formation are dominated by clays and silts that thicken seaward and that were deposited in a fluvial-deltaic environment (Van Siclen 1991). The Beaumont formation and overlying recent alluvial soils make up the uppermost units of the Chicot Aquifer (Figure 10) (USGS 2002).

The local water table (i.e., shallow groundwater) is found near land surface in the shallow alluvium sediments, generally at the approximate elevation of the San Jacinto River water surface. Groundwater movement in the shallow alluvium in the area is dominated by surface water and groundwater interactions with the river, which surrounds the former impoundments north of I-10 and the area to the south. This reach of the San Jacinto River watershed is characterized by extremely flat groundwater gradients indicating that the area surrounding the site is an area of minimal recharge to the aquifers. The Beaumont Formation is a confining unit that isolates shallow groundwater in the Holocene alluvium and in the San Jacinto River sediments from the underlying formations of the Chicot Aquifer.

## Habitats Overview

The site is located in a low-gradient, tidal estuary near the confluence of the San Jacinto River and the Houston Ship Channel. Upland, riparian, and aquatic habitats are present.

Upland natural habitat adjacent to the San Jacinto River at and near the site is generally low-lying, with little topographic variation, and consists primarily of clay and sand that supports forest communities of loblolly pine-sweetgum, loblolly pine-shortleaf pine, water oak-elm, pecan-elm, and willow oak-blackgum (Texas State Historical Association 2009). Upland natural habitat occurs along narrow sections of land on either side of the river, as well as on several small islands, to the north and south of I-10 and east of the northern impoundments. Most of these islands are vegetated with a mixture of shrubs and trees, with fringing shallow waters.

Habitats on the northern portion of the site include shallow and deep estuarine waters, and shoreline areas occupied by estuarine riparian vegetation. The in-water portion of the site is unvegetated, with a deep (20- to 30-foot) central channel and shallow (3 feet or less) sides (National Oceanic and Atmospheric Administration 1995; Clark et al. 1999). Except in the northern impoundments, sediments have a high sand content and are characterized by low organic matter content (0.5 and 2 percent TOC). By contrast, most surface sediment samples collected within the northern impoundments ranged between 1 and 5 percent TOC, with the fraction consisting of sand ranging from 4 to 98 percent, and an average of about 50 percent sands.

A sandy intertidal zone is present along the shoreline throughout much of the Site. Minimal habitat is present in the upland sand separation area located adjacent to the northern impoundments, because demolition and closure of this former industrial area created a denuded upland with a covering of crushed cement and sand. The sandy shoreline of this area is littered with riprap, other metal debris, and piles of cement fragments. Prior to implementation of the TCRA, estuarine riparian vegetation lined the upland area that runs parallel to and north of I-10. As a result of the TCRA, that area now includes a dirt road. The western cell of the impoundments north of I-10 had been occupied by estuarine riparian vegetation to the west of the central berm until the recent implementation of the TCRA, when the vegetation was removed. The eastern cell, also completely covered as a result of the TCRA, lies within intertidal and subtidal habitats.

Throughout the broader surrounding area, there are approximately 55 additional acres of freshwater, estuarine, and marine wetlands (Figure 11). The vegetation associated with the estuarine intertidal wetland documented on the northern impoundments is no longer present as a result of the TCRA, but could return over time. Major vegetation associated with fringe wetland areas included broadleaf cattail, saltmeadow cordgrass, saltmarsh aster, and marsh elder. Wetland habitats to the south of I-10 along the eastern side of the channel include a narrow stretch of vegetation along the shoreline and the shoreline habitats of three small islands south of I-10. The vegetation on the islands mainly consists of shrubs and small trees.

### **2.5.2 Conceptual Site Model**

A conceptual site model is a written description and a visual representation of the predicted relationship between a stressor and a potential receptor that describes the potential sources, release mechanisms, transport pathways, and environmental exposure media of chemicals to receptors. The conceptual site model provides a framework that facilitates application of the risk assessment process to the conditions and use of a site. Separate conceptual site models have been developed for the area north of I-10 and aquatic environment, and the area south of I-10.

#### **North of I-10 and Aquatic Environment Conceptual Site Model**

The conceptual site model for the area north of I-10 and aquatic environment is shown in Figure 12. Figure 13 identifies the potential routes of human exposure in detail and indicates whether they are considered significant or minor. For this area, hypothetical recreational and subsistence fishers, recreational visitors, and trespassers were identified as groups that may have contact with impacted media under baseline conditions.

Fishing activity within the waters surrounding the site has been observed, and fishers in this area have been reported to collect whatever they catch. However, little information is available about the type and amount of fishing that occurs. Fishers may potentially be exposed to chemicals of potential concern (COPCs) via direct contact with sediments and soils, and by ingesting fish or shellfish that have been exposed to impacted media. They may also potentially be exposed to COPCs through direct contact with surface water (ingestion and dermal contact) or porewater (dermal contact), and through inhalation of COPCs as particulates or vapors in air; however, exposures via these media and routes are considered to be minor (Figure 13).

Although the lands at and near the site are largely privately owned, points of access were available to the public along and within this area under baseline conditions. Such access allowed for a variety of recreational activities other than fishing, including picnicking, walking, bird watching, wading, and boating. Shoreline use and wading at the site has been reported prior to construction of the temporary cap; recreational visitors could have potentially been exposed via the same direct contact exposure routes as fishers (i.e., incidental ingestion of and dermal contact with soils and sediments). However, these individuals are not exposed via ingestion of fish or shellfish.

Signs of trespassing have been reported in some areas at the site, particularly under the I-10 Bridge. The hypothetical trespasser is the receptor used to represent a very low level of possible exposure. Therefore, although a hypothetical trespasser could be exposed via the same pathways as the recreational visitor (i.e., direct contact pathways) and recreational fisher (i.e., ingestion of fish and shellfish), the concept of the trespasser is that of a person whose exposure would likely be intermittent and of a shorter term than the exposures being evaluated for either of those scenarios. Thus, for the area north of I-10, the estimated risks and hazards presented for the hypothetical fishers and hypothetical recreational visitors are higher than and would overstate potential risks for hypothetical trespassers. Therefore, the hypothetical trespasser scenario was not evaluated quantitatively for the area north of I-10 and aquatic environment.

### **South of I-10 Conceptual Site Model**

The conceptual site model for the area of investigation on the peninsula south of I-10 is shown in Figure 14. Figure 15 describes the specific routes of potential exposure in detail. For this area, trespassers, commercial workers, and construction workers were identified as groups that may potentially come into contact with impacted media.

With signs of trespassing in areas along the western bank of the river at this site, it is possible that trespassers might walk around or spend time in the area of investigation on the peninsula south of I-10. Because such activities might result in direct contact with surface soil, potentially complete exposure pathways for the trespasser are incidental ingestion and dermal contact with soil. Because fencing and active management and use of industrial properties south of I-10 make this area largely inaccessible, however, it is anticipated that the trespasser's exposure would be infrequent. Also it is likely that trespassing activities by any given individual would be limited to a relatively short time frame (i.e., no more than a few years).

Land use on the peninsula south of I-10 is commercial/industrial. Commercial workers, who perform maintenance or other work-related outdoor activities, might have potential direct contact with surface and shallow subsurface soil. Potentially complete exposure pathways for the commercial worker are incidental ingestion and dermal contact with surface and shallow subsurface soil.

In the future, construction work could occur in the area of investigation on the peninsula south of I-10. Under this future scenario, construction workers may have direct contact with surface and subsurface soil. Potentially complete exposure pathways for the construction worker are incidental ingestion and dermal contact with surface and subsurface soils.

#### **2.5.3 Nature and Extent of Contamination**

The RI Report (Integral and Anchor 2013a) contains a detailed discussion of the process involved to identify COCs and the nature and extent of contamination (RI Report, Section 5.2 for the area north of I-10 and Section 6.2 for the area south of I-10). Results of the baseline human health risk assessment (BHHRA) and baseline ecological risk assessment (BERA), indicate COCs include dioxins and furans, and polychlorinated biphenyls (PCBs) (discussed in Section 2.7 of this ROD). This section discusses the nature and extent of contamination focusing on these COCs. The information is from the RI report (Integral and Anchor 2013a), unless otherwise noted.

Between 2010 and 2013, site-specific data were collected for the remedial investigation. The remedial investigation included the collection of paper mill waste, sediment, tissue (i.e., hardhead catfish, Gulf killifish, rangia clam, and blue crabs), soil, and groundwater samples for analyses including dioxins and furans, PCBs as Aroclors, metals, semivolatile organic compounds, volatile organic compounds, and pesticides. Physical data collected during the remedial investigation included: a bathymetric survey, current velocity, material, geotechnical, riverbed properties, sediment loading, erosion rates of cohesive sediment, and net sedimentation rates. Solid-phase micro extraction (SPME) porewater samplers were also evaluated as part of the RI. The RI did not include surface water sampling of the San Jacinto River.

Three hundred and fifty-seven sediment samples were collected during the RI to evaluate the nature and extent of contamination, exposure, and determine an appropriate background tissue location. Sediment samples were collected from 0 to 6 inches, 6 to 12 inches, or in 1-foot intervals at depths ranging from 3 to 10 feet. Sediment samples were analyzed for a combination of the following analyses: dioxins and furans, PCBs, metals, SVOCs, volatile organic compounds (VOC), grain size, and total organic carbon (TOC).

One hundred eighty-three tissue samples were collected during the RI to provide sufficient data to complete the baseline human health and ecological risk assessments and to evaluate biota-sediment relationships. Skin off fillets were collected from 50 hardhead catfish. The remainders of 18 hardhead catfish fillets from the fillet samples were also collected for analysis. Eighteen whole-body Gulf killifish were collected. The edible tissue from 35 common rangia clams was collected. The edible tissue from 50 blue crabs was collected. The remainders of crab after edible tissue was removed was analyzed for 12 blue crab samples. These tissue and remainder samples were analyzed for dioxins and furans and a subset were analyzed for PCBs, metals, and SVOCs.

Three hundred ninety-two soil samples were collected during the RI to evaluate the nature and extent of contamination, exposure, fate and transport, and document right-of-way conditions. Soil samples were analyzed for a combination of the following analyses: dioxins and furans, PCBs, metals, SVOCs, VOCs, grain size, and TOC. An even smaller subset of samples was analyzed for pesticides, PCBs as Aroclors, and asbestos.

A total of twenty-one monitoring wells were installed during the RI. Initially, three well pairs were located on the berms of the northern impoundments and one well within the wastes of the western cell of the northern impoundment. These wells were plugged and abandoned prior to construction of the temporary cap. More recently, four monitoring wells were installed in the northern impoundment on the berms and these wells still remain. Ten monitoring wells in the area of investigation south of I-10 were installed and still remain. Groundwater samples were collected from the monitoring wells and analyzed for dioxins and furans, PCBs, metals, SVOCs, VOCs in some cases, and total suspended solids to evaluate the nature and extent of contamination and the fate and transport of contaminants.

Physical data collected during the RI included: a bathymetric survey, current velocity (included surface water elevation and salinity), material, geotechnical, and riverbed properties, sediment load, erosion rates of cohesive sediment, and net sedimentation rates (through profiling vertical distribution of radioisotopes) (Integral and Anchor 2013a).

In addition to requirements of the *Operations, Monitoring, and Maintenance Plan* (Anchor 2011), discussed in Section 2.2.5, a porewater assessment was performed to evaluate the effectiveness of the TCRA armored cap. Porewater SPME samplers were deployed at 14 locations within the northern waste pits cap, and retrieved. The sampling objective was to collect data on dioxins and furans in porewater in order to determine if vertical gradients in concentrations of dioxins and furans in cap porewater exist and to determine if porewater concentrations in the cap differ from concentrations in surface water above the cap.

The results of the RI are documented in other sections of this ROD, where relevant.

## Surface Water

The following discussion describes the spatial extent of dioxin and furan concentrations in surface water upstream and downstream the Site, including samples taken directly above the eastern cell of the waste pits north of I-10.

Prior to the TCRA, the Texas Commission on Environmental Quality (TCEQ) Total Daily Maximum Loads (TMDL) Program collected surface water samples throughout the San Jacinto River. Samples were collected between 2002 and 2009. Upstream and downstream samples in the vicinity of the Site were generally well above the Texas Surface Water Quality Standard (TSWQS) for dioxins/furans of 0.0797 pg/L TEQ. [30 Texas Administrative Code §307.6(d)(a)(A) and (B) and §307.10]. This TSWQS was developed for the protection of human health from the consumption of fish and other aquatic life potentially exposed to surface waters contaminated with dioxins/furans.

TMDL results for dioxins TEQ over the eastern cell were higher than samples collected upstream of the site. The highest average concentration was observed directly above the eastern cell (8.61 pg/L TEQ in 2009). Tables 1 and 2 summarize the results from previous TMDL samples as well as the 2016 sampling. Average concentrations downstream of the Site ranged between 3.51 pg/L TEQ in 2003 and 0.418 pg/L TEQ in 2002, generally trending downward with distance (Integral, 2016).

In July, 2016, surface water samples were collected at seven locations (Figure 16) once per week during each of three consecutive weeks. Sampling stations were at five locations previously sampled by the TCEQ's TMDL program from 2002 to 2004, and two new stations. The same methods used by the TMDL program were used in 2016 to enable direct comparisons of current and past conditions. The study was designed to allow this comparison, and to provide information on trends across a large area, including the presence of dioxins and furans in surface waters upstream and downstream of USEPA's preliminary Site perimeter.

Results of the 2016 surface water quality study showed that average TEQ in the vicinity of the site remained above the TSWQS (Table 3). The highest average concentration of 0.681 pg/L TEQ remained directly above the eastern cell, and the lowest average downstream concentration was 0.319 pg/L TEQ (Integral, 2016). Although the greatest change (>90% decrease) in TEQ between past and current conditions occurred at the station located directly above the eastern cell of the waste impoundments north of I-10 (Integral, 2016), the average concentration of TCDD (0.386 pg/L) above the waste impoundments remained 3.5 times on average higher than the upstream concentration (0.118 pg/L).

The average concentration of TCDF (1.169 pg/L) directly above the eastern cell of the waste pits remained 3.9 times average higher than upstream levels. TCDD and TCDF are forms of dioxin and furan specifically associated with the site waste. The second greatest change (85% decrease) was at the station just downstream of the northern impoundments, under the I-10 bridge.

### North of I-10 Soil Dioxin

The following discussion describes the spatial extent of dioxin and furan concentrations in soils north of I-10, including the samples collected underneath I-10 in the Texas Department of Transportation (TxDOT) Right-of-Way.

The highest averages of dioxin and furan concentrations in surface soils north of I-10 occur in Soil Investigation Area 3 (Figure 17 and Table 4), which encompasses the northern impoundments. In Soil Investigation Area 3, the maximum TEQ concentration in surface soils (11,200 ng/kg) occurs in the southern portion of the western cell of the impoundments. Within Soil Investigation Area 3, the congener with the highest average concentration was 2,3,7,8-tetrachlorodibenzofuran (TCDF), at 6,680 ng/kg (Table 4). Average and maximum TEQ concentrations in surface soils in Soil Investigation Areas 1 (upland sand separation area) and 2 (TxDOT ROW beneath the I-10 bridge) are much lower than those within the Soil Investigation Area 3 (the northern impoundments).

In subsurface soils north of I-10, the highest average concentration of dioxins and furans also occurs in Soil Investigation Area 3 (Table 5). In Soil Investigation Area 3, the highest TEQ value in subsurface soils (16,200 ng/kg) occurs in the southern portion of the western cell (Figure 17). Consistent with surface soils within Soil Investigation Area 3, the highest average concentration for an individual congener was for 2,3,7,8-TCDF at 17,000 ng/kg (Table 5).

As with the surface soils, subsurface soil TEQ concentrations in Soil Investigation Areas 1 and 2 are lower than those within Area 3, the northern impoundments. The maximum TEQ concentration in subsurface soils of Soil Investigation Area 1 was 195 ng/kg and occurs in the 12- to 24-inch interval, in the northeastern corner of the upland sand separation area. The maximum TEQ concentration in subsurface soils of Soil Investigation Area 2 was 1.2 ng/kg

### North of I-10 Soil PCBs

Outside of the northern impoundment perimeter and within soils north of I-10, Aroclors were detected in five samples from Soil Investigation Area 2, and were estimated (J-qualified) in four of those. Aroclor 1254 was detected in soil from Station TxDOT002 at 130 µg/kg. Aroclors were not detected in surface and shallow subsurface soils of the upland sand separation area.

Because Aroclors were generally not detected in soils of Soil Investigation Area 1 and were rarely detected in Area 2 soils, only the dioxin-like PCB congener data (as TEQ<sub>P,M</sub>) are used in figures, tables, and text supporting descriptions of the nature and extent of PCBs in soils. The data for dioxin-like PCB congeners provide a description over the widest possible geographical area. Aroclors 1242, 1248, 1254, and 1260 have at least one dioxin-like PCB present at greater than 0.5 percent (Frame et al. 1996); the dioxin-like congeners are therefore a reasonable surrogate for the presence of these Aroclors.

Two of the TxDOT stations in Soil Investigation Area 2 fall within the original perimeter of the impoundments north of I-10. The sample from one of these (TxDOT005) has the highest TEQ<sub>P,M</sub> of all 14 soil samples (2.83 ng/kg; Figure 18). The second highest TEQ<sub>P,M</sub> concentration (2.23 ng/kg) was found at the location in Soil Investigation Area 2 furthest west of the northern

impoundments, Station TxDOT007. There is no evident spatial pattern in the data for TEQ<sub>P,M</sub> in soils that would suggest that the impoundments north of I-10 are an important source of dioxin-like PCBs in soils. The result for Station TxDOT007 suggests that the distribution of these dioxin-like PCBs in soils north of I-10 and in the TxDOT ROW is random, and likely reflects background conditions. There are no site-specific background data for PCB congeners.

### **North of I-10 Groundwater Dioxin**

In five of the seven initial monitoring wells installed north of I-10 (Figure 19), no dioxin and furan congeners were detected. These five wells include two of the shallow wells in GWBU-A (the alluvial groundwater) and all three deep wells in GWBU-B (the unit below the Beaumont clay). One dioxin and one furan congener were detected in a well screened in GWBU-A (SJMWS02) at estimated concentrations of 3.6 picograms per liter (pg/L) (octachlorinated dibenzo-p-dioxin [OCDD]) and 1.89 pg/L (2,3,7,8-TCDF).

In the shallow perched groundwater sample within the waste in the northern impoundments, SJMWS04, all but 4 of the 17 dioxin and furan congeners were detected or estimated at concentrations ranging from 14 pg/L to 9,100 pg/L (Table 6). This well was screened within the upper 2.5 feet of waste material in the impoundment. 2,3,7,8-TCDD was detected at a concentration of 2,700 pg/L. This is the only detection (estimated or otherwise) of 2,3,7,8-TCDD in any well north of I-10.

### **North of I-10 Groundwater PCBs**

PCBs were analyzed as Aroclors only in the groundwater samples from locations within the perimeter of the impoundments north of I-10. Aroclors were not detected in any groundwater samples (Table 6). Matrix interferences in sample SJMWS04 likely resulted in elevated detection limits for Aroclors (Table 6).

### **Sediment and Waste Material Dioxin/Furan**

The spatial distribution of dioxin/furan in surface and subsurface waste material in the impoundments and sediments is shown in Figures 20 and 21. Summary statistics for results of dioxin/furan as well as the individual dioxin and furan congeners on a dry-weight basis for surface and subsurface sediments are provided in Tables 7 and 8.

In the baseline dataset, the spatial extent of dioxins and furans in sediment is well-defined. Dioxin and furan concentrations in sediments, expressed as TEQ results, are higher within the perimeter of the impoundments north of I-10 than elsewhere at the site. Within the perimeter of the impoundments north of I-10, dioxin/furan results in sediments are highest in the western cell. Dioxin/furan results in sediment outside of the northern impoundments are typically 3 to 4 orders of magnitude lower than those within the impoundments, even in areas directly adjacent to the impoundment perimeter.

The highest dioxin/furan result (43,000 ng/kg TEQ) occurs in surface waste material in the northwest portion of the impoundments, and the second highest (31,600 ng/kg TEQ) occurs in the uppermost 2-foot interval of the core the boring located in the north-central portion of the northern impoundments (Figure 20); cores surrounding it to the north, east, and southeast show

much lower concentrations at all intervals, even within the impoundment perimeter. Cores within the western cell tend to show higher dioxin/furan results throughout the upper core increments. Dioxin/furan results generally decrease from their maximum with depth within a given core indicating that the peak concentrations have been located in the vertical dimension.

The highest dioxin levels outside of the waste pits are in the sand separation area, which is located in the San Jacinto River approximately 1000 feet northwest from the waste pits. The sand separation area (Figure 2) is where sand was separated from the rest of the dredged material during sand mining. Dioxin/furan results in surface sediment samples from two locations adjacent to the upland sand separation area are above 100 ng/kg, at estimated concentrations of 121 ng/kg (Station SJNE041) and 153 ng/kg (Station SJNE032). All other dioxin/furan results in surface sediment outside of the impoundment perimeter are generally much lower. While some of the surface sediment dioxin levels outside of the waste pits are above the cleanup level of 30 ng/kg TEQ dioxin, the average for the area within EPA's Preliminary Site Perimeter is 16.1 ng/kg.

In the vicinity of the upland sand separation area (Station SJNE032), two deep subsurface intervals (4 to 5 feet and 7 to 8 feet below mudline) have TEQ levels of 349 and 339 ng/kg, respectively, the highest dioxin/furan level measured outside the northern impoundment perimeter. However, because these results are only contained in two samples, the EPA does not believe these results are representative of the area, and additional sediment sampling will be conducted there during the Remedial Design.

In the vicinity of the Southern Impoundment, surface sediment samples around the southern end (generally downstream) contain dioxin/furan at 74.6 ng/kg, 52.6 ng/kg, 50.9 ng/kg, and 49.3 ng/kg (Figure 20). The highest subsurface sediment sample in this area was 133 ng/kg dioxin/furan TEQ adjacent to the southwest part of the Southern Impoundment. These results indicate a waste material release from the Southern Impoundment because the sediment results north of these sample locations, but south of the northern waste pits, are much lower and indicative of background values

### **Sediment and Waste Material PCBs**

The distribution of PCB TEQ<sub>P,M</sub> concentrations in surface and subsurface sediments and waste material is shown in Figures 22 and 23, respectively. Summary statistics for PCBs in surface sediments and waste materials are listed in Table 9, and for subsurface sediments and waste materials in Table 10. PCB congener detection frequency ranges from 0 for PCB congener 169 in subsurface samples to 87 percent for PCB congener 105 in surface samples. In surface samples, PCB congeners 105, 118, and 156/157 have a greater than 80 percent detection frequency, while PCB congeners 81, 126, and 169 were detected in less than 20 percent of the samples.

PCB TEQ<sub>P,M</sub> concentrations are highest in samples collected from within the perimeter of the impoundments north of I-10, with the maximum value of 38.1 ng/kg from the 4- to 6-foot depth interval in core SJGB012 (Figure 23). The PCB TEQ<sub>P,M</sub> concentrations in most surface and subsurface samples within the northern impoundment exceed 1 ng/kg, while all but two values outside of the northern impoundment are below 1 ng/kg. The exceptions are one surface and one subsurface sample location along the northwest portion of the peninsula south of I-10. These are

in the surface interval at Station SJSD004 (6.85 ng/kg), and in the 12- to 24-inch depth interval of SJSD002 (1.58 ng/kg).

Concentrations of PCBs were either significantly correlated with concentrations of dioxins or were non-detect.

### **Tissue Dioxin/Furan**

Tissue samples were collected from three site fish collection areas (FCAs) presented on Figure 24:

- FCA 1 – Downstream of I-10 (identified as SJFCA1 on Figure 24)
- FCA 2 – In the area surrounding the impoundments north of I-10 and the upland sand separation area (identified as SJFCA2 on Figure 24)
- FCA 3 – Upstream of the northern impoundments and upland separation area (identified as SJFCA3 on Figure 24).

Dioxins and furans were generally detected in tissue samples collected at the site and from background locations. In some samples, many congeners were never detected. Data for blue crab, hardhead catfish, clams, and Gulf killifish are summarized in this section.

Mean dioxin/furan results in edible blue crab tissue range from 0.146 ng/kg at FCA 3 to 0.739 ng/kg in FCA 1 (Table 11). Means for edible crab tissue in FCA 2 and FCA 3 at 0.23 and 0.146 ng/kg, respectively, are closer to the background mean (0.157 ng/kg) than to the mean in FCA 1. In all FCAs, 2,3,7,8-TCDF has the highest mean and the highest individual concentrations among the dioxin and furan congeners in crab tissue.

Mean TEQ results in hardhead catfish fillet range from 2.94 in FCA 1 to 3.87 ng/kg in FCA 2 with the highest mean and the highest maximum in FCA 2 (Table 12). The overall range of TEQ concentrations in catfish fillet from FCAs 1 through 3 is 0.801 ng/kg in FCA 1 to 5.85 ng/kg in FCA 2, with the three maximum values for the three FCAs being fairly similar.

Edible clam (common rangia) tissues had the highest mean and maximum TEQ results within the site perimeter, with both the highest mean and the highest maximum in FCA 2. The mean TEQ in clams in FCA 2 is 7.89 ng/kg, where the maximum TEQ is 27 ng/kg, nearly as high as the maxima for whole catfish in FCA 1 and FCA 2. In addition, all but three dioxin and furan congeners were detected at least once in FCA 2; in all other areas (including background), the same four congeners were detected in clams: 2,3,7,8-TCDD, 1,2,3,4,6,7,8- heptachlorodibenzo-p-dioxin (HpCDD), 2,3,7,8-TCDF, and OCDD (Table 13). Other congeners were never detected in clams from FCA 1 and FCA 3 nor in clams from upstream.

Dioxins and furans were never detected in killifish samples from FCA 1, and only two dioxin congeners (1,2,3,4,6,7,8-HpCDD and OCDD) and one furan congener (2,3,7,8-TCDF) were detected in killifish from FCA 3 (Table 14). A total of seven dioxin and furan congeners (2,3,7,8-TCDD, 1,2,3,4,6,7,8-HpCDD, OCDD, 2,3,7,8-TCDF, 2,3,4,7,8-pentachlorodibenzo-furan,

1,2,3,4,7,8-hexachlorodibenzofuran [HxCDF], and 1,2,3,6,7,8-HxCDF) were detected in killifish from FCA 2. The maximum TEQ concentration in killifish (10.1 ng/kg) was in killifish from FCA 2.

Stepwise statistical analysis supported pooling of data for hardhead catfish fillet and crab tissue data for FCA 2 and FCA 3 and supported pooling of data for clam tissue data for FCA 1 and FCA 3.

### **Tissue PCBs**

As described above, tissue samples were collected from three site FCAs (Figure 24). PCBs were detected in all edible and whole crab samples, including those from background. Like dioxins and furans, total PCB concentrations (as the sum of all congeners with nondetects set to one-half the detection limit) are higher in whole crab than in edible crab (Table 11). Among edible crab samples, background minimum, maximum, and mean total PCB concentrations are 0.55 µg/kg, 2.1 µg/kg, and 1.29 µg/kg, respectively. At the site, mean total PCB concentrations in edible crab tissue range from 2.0 µg/kg in FCA 1 to 7.4 µg/kg in FCA 2.

Therefore, the mean PCB concentration in edible crab was higher at the Site (7.4 µg/kg at FCA 2) than for background areas (1.29 µg/kg). Similarly, the highest mean TEQ<sub>P,M</sub> occurs in FCA 2, where the overall maximum TEQ<sub>P,M</sub> also occurs. The spatial pattern of PCBs in crab is therefore different from that of dioxins and furans as TEQ for which the highest concentrations in crab tissue are in FCA 1.

PCBs were detected in all catfish samples (Table 12). Total PCB concentrations are higher in whole catfish tissue samples than in catfish fillet, both from at the Site and in Cedar Bayou. Total PCBs in Cedar Bayou catfish fillet samples range from 25.5 to 88.4 µg/kg, with a mean total PCB concentration of 46.5 µg/kg. At the Site, the mean total PCB concentrations in catfish fillet ranges from 97.7 µg/kg in FCA 1 to 107 µg/kg in FCA 3.

Therefore, the mean PCB concentration in catfish fillets was higher at the Site (107 µg/kg at FCA3) than for background (46.5 µg/kg). The smallest range in total PCB concentrations in catfish fillet occurs in FCA 2, which has the highest minimum among the FCAs. Mean and median total PCB concentrations in catfish tissue samples from all three FCAs are greater than those in catfish collected from the Cedar Bayou background sampling area.

In contrast to TEQ in catfish fillet tissue, the highest maximum and mean concentrations for TEQ<sub>P,M</sub> are in fish from FCA 3 at 2.79 ng/kg and 1.36 ng/kg, respectively. Patterns are similar for whole catfish, except the highest maximum is in FCA 3 while the highest mean is in FCA 1. In whole catfish from all three FCAs, differences in the TEQ<sub>P,M</sub> concentrations at the site relative to those from Cedar Bayou are much smaller than the differences between these two locations for TEQ.

PCBs were detected in all edible clam tissue samples, including background (Table 13). At the site, mean total PCB concentrations ranges from 23.6 µg/kg in FCA 1 to 46.1 µg/kg in FCA 2. The range is 20.2 µg/kg in FCA 2 to 95.4 µg/kg in FCA 2. Background minimum, maximum, and mean total PCB concentrations are 9.54 µg/kg, 17.8 µg/kg, and 12.9 µg/kg, respectively.

Therefore, the mean PCB concentration in edible clam tissue was higher at the Site (46.1 µg/kg at FCA2) than for background (12.9 µg/kg). Concentrations of PCB TEQ<sub>P,M</sub> are generally lower in clams than those of dioxin/furan TEQ. The mean PCB TEQ<sub>P,M</sub> is higher in FCA 2 (0.502 ng/kg) than its mean in FCA 1 (0.22 ng/kg) or FCA 3 (0.366 ng/kg). The same pattern holds for maximum values within the three FCAs (Table 13). Clams from FCA 1 have the lowest maximum (0.271 ng/kg) and the lowest median (0.225 ng/kg) PCB TEQ<sub>P,M</sub> concentrations. In comparison, the minimum, maximum, and mean upstream background PCB TEQ<sub>P,M</sub> concentrations are 0.118 ng/kg, 0.283 ng/kg, and 0.181 ng/kg, respectively. Concentrations of PCB TEQ<sub>P,M</sub> in clams (and killifish) are not significantly different in FCA 1 than in the upstream background area.

PCBs were detected in all Gulf killifish tissue samples, including in upstream background samples (Table 14). At the site, mean total PCB concentrations range from 36.2 µg/kg in FCA 1 to 82.6 µg/kg in FCA 2. The maximum PCB TEQ<sub>P,M</sub> concentration in killifish (2.92 ng/kg) is also for FCA 2. Background minimum, maximum, and mean total PCB concentrations are 10.2 µg/kg, 14.6 µg/kg, and 12 µg/kg, respectively. Mean total PCB concentrations detected Gulf killifish tissue samples at the site are significantly greater than in background Gulf killifish tissue, but TEQ<sub>P,M</sub> is not significantly different in FCA 1 or FCA 3 than in background.

### **South of I-10 Soil Dioxin/Furan**

Dioxin/furan concentrations in surface soil from Soil Investigation Area 4 (southern impoundment) and adjacent sampled areas range from 1.35 to 36.9 ng/kg (Table 15). Dioxin/furan concentrations above 30 ng/kg in surface soil occur at both the southern (Stations SJSB023 and SJSB024) and northern (Stations SJSB001 and SJSB014) ends of Soil Investigation Area 4 (Figure 25). These are the only locations where dioxin/furan in surface soils exceeds the surface soil reference envelope value for this parameter of 24.3 ng/kg.

A reference envelope value incorporates the use of tolerance limits on the background area data to define a threshold for comparisons of individual stations or samples. Such comparisons allow determination of whether the concentration of a chemical in an individual sample is or is not consistent with the background condition. The statistical representation of the reference envelope value is a one-sided upper tolerance limit on an upper percentile of the background data, derived to characterize background conditions. Tolerance intervals are a type of statistical interval that defines the limits within which a certain proportion of a population falls, given a predetermined confidence level. The resulting comparison would indicate, for an individual sample with a concentration greater than the reference envelope value, that there is at least a 95 percent chance ( $\alpha = 0.05$ ) that the concentration in the sample is greater than expected for the highest 5 percent of all background results.

Substantially lower concentrations including the minimum dioxin/furan concentration of 1.35 ng/kg are found at stations in close proximity to those that exceed the surface soil reference envelope value, indicating that these few slightly elevated dioxin/furan concentrations are localized. The average surface soil dioxin/furan in Soil Investigation Area 4 and adjacent areas is most similar to that of Soil Investigation Area 2, beneath I-10, in the TxDOT Right-of-Way (Table 4). Within Soil Investigation Area 4 (southern impoundment), the congener with the

highest concentration in surface soil is OCDD, at 64,900 ng/kg (Table 15). TCDD concentrations range up to 24.3 ng/kg.

In subsurface soils from 6 to 24 inches, dioxin/furan results range from 0.134 to 303 ng/kg, with an average of 16.5 ng/kg (Figure 25). The second highest result in this depth interval (43.1 ng/kg at Station SJSB018) is much lower than the maximum (Figure 25). The average dioxin/furan result in subsurface soils from 6 to 24 inches deep is slightly greater in the area of investigation on the peninsula south of I-10 than north of I-10, which includes the upland sand separation area and the nearby access road north of I-10 (Table 5). As for surface soils, the congener with the highest results in subsurface soils collected south of I-10 is OCDD at 106,000 ng/kg (Table 16).

Dioxin/furan concentrations in the southern impoundment soils significantly increase at a depth greater than 2 feet. The dioxin/furan results deeper than 2 feet range from 0.092 to 50,100 ng/kg and average 743 ng/kg (Table 17). The maximum core sample dioxin/furan occurs at a depth of 6 to 8 feet and is at Station SJSB019 in the southern part of soil investigation area 4 (Figure 25). Station SJSB023 has the second-highest TEQ concentration (35,500 ng/kg, at depth interval of 4 to 6 feet [Figure 25]); the highest concentration in surface soils is also found at this location. The majority of the highest core sample dioxin/furan concentrations occur between 6 and 12 feet deep, and are associated with stations located near the center of the peninsula south of I-10.

### **South of I-10 Soil PCB**

PCB concentrations were measured in Soil Investigation Area 4 soils as Aroclors in 2011 and then as congeners in 2012. Total PCB concentrations in surface soil from Soil Investigation Area 4 range from 1.05 to 468 µg/kg, with an average concentration of 98 µg/kg (Table 18). The highest concentrations in surface soil occur in the southern portion of Soil Investigation Area 4 (Figure 26), with the maximum concentrations found at Stations SJSB018 and SJSB019; others in the same area range from 141 to 374 µg/kg. The lowest concentrations, by contrast, occur in the northern portion of the Soil Investigation Area 4.

Total PCB concentrations in Soil Investigation Area 4 subsurface soil range from 0.97 to 838 µg/kg and average 105 µg/kg (Table 18). The general pattern of total PCB distribution in the subsurface soil mirrors that of the surface soil (Figure 26). The maximum subsurface concentrations occur at Stations SJSB018 and SJSB019 in the south-central part of Soil Investigation Area 4. The lowest concentrations are located in the northern portion of Soil Investigation Area 4.

Total PCB concentrations in soil deeper than 2 feet range from 0.25 to 6,590 µg/kg, with an average concentration of 348 µg/kg (Table 18). The maximum concentrations occur at Station SJSB023 at a depth of 4 feet (Figure 26). This result at depth at Station SJSB023 corresponds to the second-highest TEQ<sub>DF,M</sub> concentration in soils (of 35,500 ng/kg). The next highest total PCB concentrations occur at Stations SJSB015 (5,960 µg/kg at 12 feet) and SJSB019 (3,270 µg/kg at 8 feet). At both stations, the elevated total PCB concentration corresponds to a sample where TEQ<sub>DF,M</sub> is also elevated (2,950 ng/kg at Station SJSB015 and 50,100 ng/kg at Station SJSB019). The majority of the highest total PCB concentrations are found deeper than 4 feet, and many occur in soils deeper than 6 feet. Higher total PCB concentrations occur evenly distributed across Soil Investigation Area 4 in the deep soils, a

departure from the pattern evident at shallower depths.

### **South of I-10 Groundwater**

Three or more dioxin and furan congeners were detected within the waste material in all three monitoring wells south of I-10. For those that were detected, the highest concentrations consistently occur in SJMW001. The dioxin/furan result in SJMW001 of 47.3 pg/L within the waste material. The average concentration of 2,3,7,8-TCDD in the waste material in all wells is 17.1 pg/L (using the estimated result in SJMW002 of 8.92 pg/L and the detection limit in SJMW003 of 9.9 pg/L). Table 19 presents summary statistics for groundwater samples collected south of I-10.

### **2.5.4 Chemical Fate and Transport**

Section 5.6 of the RI Report contains a summary of the chemical fate and transport processes affecting the concentrations of dioxins and furans at the site. The most significant points of this discussion are summarized in the FS (EPA 2016) and are provided below:

- Dioxins and furans break down very slowly and releases from long ago remain in the environment. Dioxins and furans are therefore classified as persistent organic pollutants.
- Sediment-water interactions – Dioxins and furans are hydrophobic and preferentially bind to particulate matter. Particulate-associated dioxins and furans within the sediment bed enter the water column through sediment deposition and erosion processes. Deposition of sediments with low concentrations of chemicals in some areas may support natural recovery. However, riverbed erosion/scour has also occurred in some areas as demonstrated by the 2016 and the 2017 flooding when eroded areas were discovered adjacent to the eastern part of the temporary cap.
- Partitioning and dissolved phase flux – Because dioxins and furans are hydrophobic, they will be present primarily in particulate form, and their fate is therefore determined largely by sediment transport processes. Dioxins and furans within the sediment matrix include dissolved-phase dioxins and furans in porewater through partitioning processes, which can result in a transfer of dissolved-phase mass to the water column under certain conditions.
- Transport in the water column – Dioxins and furans present in the water column in any phase are transported by surface water currents, which are affected by hydrodynamic processes within the larger San Jacinto River.
- External sources – Publicly owned treatment plant outfalls, other point-source discharges, storm water runoff, and atmospheric deposition are all sources of dioxins and furans, although not generally the TCDDs and TCDFs associated with the site waste. As documented in the RI Report, groundwater is not a source of dioxins or furans to the San Jacinto River.

It should also be noted that data analyses and literature review, including evaluation of region-specific multivariate datasets, indicates that the majority of dioxin and furan congeners do not consistently bioaccumulate in fish or invertebrate tissue, although this general statement is not true for the tetrachlorinated congeners found in high levels in the site waste material. Systematic predictions of bioaccumulation from concentrations of dioxins and furans in abiotic media (both sediment and water) are only possible for tetrachlorinated congeners.

## **2.6 CURRENT AND POTENTIAL FUTURE LAND AND RESOURCE USES**

This section summarizes the current and reasonably anticipated future land and resource use at the site and surrounding the site. This information forms the basis for the exposure assessment assumptions and risk characterization conclusions discussed in Section 2.7.

### **2.6.1 Land Use**

Current land use at the site is primarily industrial and commercial use, as presented on Figure 27. Current land use surrounding the site includes mixed residential and industrial uses to the west, and undeveloped or residential areas to the east and north. Immediately south of the site is commercial/industrial land use. Moving farther from the site, the amount of residential land use increases, along with other land use categories not found in the immediate vicinity, such as undeveloped land, farms, parks, and lands listed as “other” (e.g., schools and hospitals). The future land use is not anticipated to be different from the current land use.

### **2.6.2 Surface Water Use**

The San Jacinto River watershed encompasses nearly 4,000 square miles and approximately 310 miles of open streams including primary streams and tributary channels. The San Jacinto River flows from its headwaters near Huntsville, Texas through Lake Conroe and Lake Houston. The Port of Houston Authority operates the Houston Ship Channel (HSC), which originates at the Turning Basin on Buffalo Bayou and follows to the San Jacinto River. The HSC continues through the San Jacinto River and San Jacinto Bay to Galveston Bay.

South of the dam at Lake Houston, the San Jacinto River, including the area surrounding the site, is tidally influenced. The area south of the site is dominated by the HSC and the industrial sites that are served by the barges and ocean-going vessels that use the HSC. From the site north to Lake Houston there is much less industrialization along the river. The water quality segments upstream and downstream include the following uses: aquatic life, general, recreation, and restricted fish consumption.

Lynchburg Reservoir, located on the east bank of the San Jacinto River just south of the I-10 Bridge, uses water pumped in from the Trinity River. It is owned by the City of Houston, and construction was completed in 1976. At normal levels the lake has a surface area of 200 acres. The lake dam is earthen construction, with a height of 35 feet and a length of 15,315 feet. The lake capacity is 5,188 acre-feet; however, normal storage is 4,700 acre-feet. The lake drains an area of 0.32 square miles. Lost Lake (located south of I-10 between the primary channel of the San Jacinto River and the Old Channel to the west) is not a surface water reservoir; rather, it is a confined disposal facility for sediments from the HSC maintenance dredging program. It is

managed by the Port of Houston Authority and U.S. Army Corps of Engineers Galveston District.

### **Harvesting Shellfish and Fish**

Commercial and recreational fishing activity occurs throughout Galveston Bay. The San Jacinto River along with nearby Upper Galveston Bay, Tabbs Bay, and the San Jacinto State Park have “many points of public access and support both recreational and subsistence fishing activities” (Texas Department of State Health Services [TDSHS] 2005). Near the site, fishing is known to occur, however the amount and frequency of fishing has not been determined (Integral and Anchor 2013a). No known subsistence fishing communities have been documented by the Texas Department of State and Health Services in the area.

Consumption of mollusks and shellfish (clams, mussels, and oysters) taken from public fresh waters is prohibited by TDSHS. Within public salt waters, these shellfish may be taken only from waters approved by TDSHS. TDSHS shellfish harvest maps designate approved or conditionally approved harvest areas. Waters near the site are not included on these maps (TPWD 2009).

### **Other Recreational Use**

Although the Site north of I-10 is private land, access points along the San Jacinto River allowed for a variety of recreational activities including picnicking, swimming, nature walks, bird watching, wading, fishing, boating, water sports, and other shoreline uses. In the area just to the south of the I-10 Bridge on the west side of the river, children and adults have been reported to at times play along the shoreline, wade in the water, and fish (Integral and Anchor 2013a). The Southern Impoundment area is private industrial land where recreational activities are not likely allowed.

### **Potable Surface Water Use**

There are no surface water intakes within 15 miles downstream of the northern impoundments or of the peninsula south of I-10 (TCEQ 2006).

## **2.7 SUMMARY OF SITE RISKS**

The primary hazardous substances present at the Site are dioxins and furans. PCBs also contribute to the risks associated with the site, but in comparison to the dioxins and furans, they are not the risk drivers. PCBs at the site are co-located with dioxins and furans and will therefore be addressed by a remedy addressing the dioxins and furans. Dioxins are the by-products of various industrial processes (i.e., bleaching paper pulp, and chemical and pesticide manufacture) and combustion activities (i.e., burning household trash, forest fires, and waste incineration).

After being absorbed, dioxin distributes to organs according to lipid (fat) content and readily accumulates in body fat. TCDD, or 2,3,7,8-tetrachloro dibenzo-p-dioxin, is a tetrachlorinated congener of dioxin found in the site waste. The half-life of TCDD in the human body ranges from 7 to 12 years. The most common health effect in people exposed to large amounts of

dioxins, in particular TCDD, is chloracne. Chloracne cases have typically been the result of accidents or significant contamination events. Chloracne is a severe skin disease with acne-like lesions that occur mainly on the face and upper body. Other skin effects noted in people exposed to high doses of TCDD include skin rashes, discoloration, and excessive body hair (ATSDR, 1998).

In addition to chloracne, dioxins can cause several health effects, including long-term changes in glucose metabolism, subtle changes in hormone levels, transient mild liver damage (hepatotoxicity) and peripheral nerve damage (neuropathy). Other potential effects include porphyria cutanea tarda (liver dysfunction and photosensitive skin lesions), Type 2 diabetes, neurobehavioral development effects in infants, and men in highly exposed populations are less likely to father boys (ATSDR, 1998).

Noncancer adverse health effects were observed in sensitive susceptible very young members of the population during their development in utero. Increased thyroid-stimulating hormone levels in newborns born to mothers who were exposed to TCDD during the Seveso accident was reported (Baccarelli et al., 2008). Decreased sperm concentration and sperm motility in men who were exposed to TCDD during childhood during the Seveso accident was also reported and identified the first 10 years of life as a critical window of susceptibility to TCDD induced sperm effects in young children (Mocarelli et al., 2008).

TCDD carcinogenicity in animals is well established. However, the specific carcinogenic mechanism for TCDD has not been fully elucidated. TCDD produces cancer at all sites in animals. Epidemiological data support that TCDD increases cancer incidence in all sites for humans. The World Health Organization (WHO, 1997), and the U.S. National Toxicology Program (NTP, 2001). Dioxin also increases the risk for several individual cancers, including soft-tissue malignant tumor (sarcoma), lung cancer, cancer of the lymphatic tissue (non-Hodgkin's lymphoma), and malignant enlargement of the lymph nodes, spleen, and liver (Hodgkin's disease) (ATSDR, 2006).

Polychlorinated biphenyls are mixtures of up to 209 individual chlorinated compounds (known as congeners). There are no known natural sources of PCBs. PCBs are either oily liquids or solids that are colorless to light yellow. Many commercial PCB mixtures are known in the U.S. by the trade name Aroclor. PCBs were used in a variety of industrial equipment (e.g., electrical, heat transfer, and hydraulic equipment) because they don't burn easily and are good insulators and consumer products (e.g., plasticizers in paints, plastics, and rubber products). The manufacture of PCBs was stopped in the U.S. in 1977 because of evidence they build up in the environment and can cause harmful health effects (ATSDR, 2014 & EPA, 2007).

The most commonly observed health effects in people exposed to large amounts of PCBs are skin conditions such as chloracne (as described above) and rashes. Studies in exposed workers have shown changes in blood and urine that may indicate liver damage. PCB exposures in the general population are not likely to result in skin and liver effects (EPA, 2007).

The primary targets of PCBs are the endocrine (hormonal) and nervous systems. PCB exposure during prenatal and early childhood development has been associated with low birth weight,

neurobehavioral developmental delays, cognitive deficits, changes in production of thyroid hormones, and altered reproductive system development in males and females. PCB exposure has also been associated with liver cancer in experimental animals (EPA, 2007).

Most of the studies of health effects of PCBs in the general population examined children of mothers who were exposed to PCBs. Women who were exposed to relatively high levels of PCBs in the workplace or ate large amounts of fish contaminated with PCBs had babies that weighed slightly less than babies from women who did not have these exposures. Babies born to women who ate PCB-contaminated fish also showed abnormal responses in tests of infant behavior. Some of these behaviors, such as problems with motor skills and a decrease in short-term memory, lasted for several years. Other studies suggest that the immune system was affected in children born to and nursed by mothers exposed to increased levels of PCBs. The most likely way infants will be exposed to PCBs is from breast milk. In most cases, the benefits of breast-feeding outweigh any risks from exposure to PCBs in mother's milk (ATSDR, 2014).

Few studies of workers indicate that PCBs were associated with certain kinds of cancer in humans. Rats that ate food containing high levels of PCBs for two years developed liver cancer. PCBs are classified by the U.S. EPA as B2, probable human carcinogens, based on liver tumors in adult rats

([https://cfpub.epa.gov/ncea/iris/iris\\_documents/documents/subst/0294\\_summary.pdf](https://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0294_summary.pdf)) (EPA, 1996). The World Health Organization International Agency for Research on Cancer (IARC) in 1998 classified PCBs as Group 2A, probably carcinogenic in humans (<http://monographs.iarc.fr/ENG/Monographs/vol107/mono107.pdf>) (WHO, 2016).

Twelve PCB congeners show structural similarity to chlorinated dibenzo-p-dioxins and dibenzofurans, and are often referred to as "dioxin-like" PCBs. Dioxin-like congeners include the non-*ortho* PCBs 77, 81, 126, and 169 and mono-*ortho* PCBs 105, 114, 118, 123, 156, 157, 167, and 189. These dioxin-like PCBs elicit a spectrum of biochemical and toxicological responses similar to dibenzo-p-dioxins and dibenzofurans including environmental persistence and bioaccumulation in the food chain (EPA, 1996). Like dioxins and furans, dioxin-like PCB congeners have also been assigned toxic equivalency factors (TEFs) ranging from 0.1 (PCB-126) to 0.00003 relative to TCDD, which is assigned a TEF of 1 (Van den Berg, 2006).

Concentrations of these congeners in various media are multiplied by their respective TEF to yield toxic equivalent concentrations which are summed to provide a measure of total dioxin-like activity. Dioxin-like PCBs toxicity can therefore be expressed as a fraction of the toxicity of TCDD, and it is recommended that their risk also be assessed using the TEQ approach (EPA, 2010a).

A site-specific baseline human health risk assessment (BHHRA) and a baseline ecological risk assessment (BERA) were conducted to determine potential pathways by which people (human receptors) or animals (ecological receptors) could be exposed to upland or aquatic contamination in sediment, soil, water, or biota, the amount of contamination receptors of concern may be exposed to, and the toxicity of those contaminants if no action were taken to address contamination at the Site (Integral & Anchor 2013b, Integral 2013). These assessments provide the basis for taking action and identify the contaminants and exposure pathways that need to be addressed by the remedial action. Section 2.7.1 provides a summary of the relevant portions of

the BHHRA as summarized from Integral and Anchor (2013b). Section 2.7.2 provides a summary of the relevant portions of the BERA as summarized from Integral (2013). Section 2.7.3 discusses the basis for action at the site.

### 2.7.1 Summary of Human Health Risk Assessment

The baseline human health risk assessment estimates what risks the site poses if no action were taken. It provides the basis for taking action and identifies the contaminants and exposure pathways that need to be addressed by the remedial action. This section of the ROD summarizes the results of the BHHRA.

#### Identification of Chemicals of Concern

The tables below present the COCs and exposure point concentrations for each of the COCs detected in media (i.e., the concentration that was used to estimate the exposure and risk from each COC). The tables include the number of samples per exposure unit, the frequency of detection (i.e., the number of times the chemical was detected in the samples collected at the site), the exposure point concentration, and how the exposure point concentration was derived.

**Chemicals of Concern and Baseline Exposure Point Concentrations  
North of I-10 and Aquatic Environment**

Scenario Timeframe: Baseline						
Exposure Unit	Chemical of Concern	Number of Samples	Maximum Result (ng/kg)	Frequency of Detection (percent)	Exposure Point Concentration (ng/kg)	Statistical Measure
<b>Sediment</b>						
Beach Area A	TEQ(ND=1/2)	5	0.495	100	0.456	95UCL
	TEQ(ND=0)	5	0.373	100	0.339	95UCL
	Aroclors(ND=1/2)	Not Sampled	--	--	--	--
	Aroclors(ND=0)	Not Sampled	--	--	--	--
	TEQ <sub>P</sub> (ND=1/2)	Not Sampled	--	--	--	--
Beach Area B/C	TEQ <sub>P</sub> (ND=0)	Not Sampled	--	--	--	--
	TEQ(ND=1/2)	10	10.9	100	6.36	95UCL
	TEQ(ND=0)	10	10.7	100	6.12	95UCL
	Aroclors(ND=1/2)	Not Sampled	--	--	--	--
	Aroclors(ND=0)	Not Sampled	--	--	--	--
Beach Area D	TEQ <sub>P</sub> (ND=1/2)	Not Sampled	--	--	--	--
	TEQ <sub>P</sub> (ND=0)	Not Sampled	--	--	--	--
	TEQ(ND=1/2)	7	2.9	100	2.12	95UCL
	TEQ(ND=0)	7	2.8	100	2.0	95UCL
	Aroclors(ND=1/2)	Not Sampled	--	--	--	--
Beach Area E	Aroclors(ND=0)	Not Sampled	--	--	--	--
	TEQ <sub>P</sub> (ND=1/2)	Not Sampled	--	--	--	--
	TEQ <sub>P</sub> (ND=0)	Not Sampled	--	--	--	--
	TEQ(ND=1/2)	17	47,000	100	13,000	95UCL
	TEQ(ND=0)	17	46,000	100	13,000	95UCL
Tissue – Hardhead Catfish Fillet	Aroclors(ND=1/2)	4	1,400,000	0	1,400,000	Max A 1254
	Aroclors(ND=0)	4	0	0	0	Max
	TEQ <sub>P</sub> (ND=1/2)	4	4.5	100	4.5	Max
	TEQ <sub>P</sub> (ND=0)	4	2.43	100	2.35	95UCL
	TEQ(ND=1/2)	10	5.45	100	3.92	95UCL
FCA 1	TEQ(ND=0)	10	5.32	100	3.86	95UCL
	PCB <sub>C</sub> (ND=1/2)	12	156,000	100	104,000	95UCL
	PCB <sub>C</sub> (ND=0)	12	156,000	100	104,000	95UCL

FCA 2/3	TEQ <sub>P</sub> (ND=1/2)	12	2.27	100	1.67	95UCL
	TEQ <sub>P</sub> (ND=0)	12	2.17	100	1.43	95UCL
	TEQ(ND=1/2)	20	5.85	100	4.06	95UCL
	TEQ(ND=0)	20	5.84	100	3.99	95UCL
	PCB <sub>C</sub> (ND=1/2)	20	129,000	100	94,200	95UCL
	PCB <sub>C</sub> (ND=0)	20	129,000	100	94,200	95UCL
	TEQ <sub>P</sub> (ND=1/2)	20	2.79	100	1.57	95UCL
	TEQ <sub>P</sub> (ND=0)	20	2.7	100	2.38	95UCL

**Chemicals of Concern and Baseline Exposure Point Concentrations  
North of I-10 and Aquatic Environment (Continued)**

Scenario Timeframe: Baseline						
Exposure Unit	Chemical of Concern	Number of Samples	Maximum Result (ng/kg)	Frequency of Detection (percent)	Exposure Point Concentration (ng/kg)	Statistical Measure
<b>Tissue – Edible Clam</b>						
FCA 1/3	TEQ(ND=1/2)	10	2.19	100	1.65	95UCL
	TEQ(ND=0)	10	2.12	100	1.51	95UCL
	PCB <sub>C</sub> (ND=1/2)	10	26,900	100	21,700	95UCL
	PCB <sub>C</sub> (ND=0)	10	26,900	100	21,600	95UCL
	TEQ <sub>P</sub> (ND=1/2)	10	0.436	100	0.346	95UCL
	TEQ <sub>P</sub> (ND=0)	10	0.104	100	0.0802	95UCL
FCA 2	TEQ(ND=1/2)	15	27	100	19	95UCL
	TEQ(ND=0)	15	26.9	100	21.4	95UCL
	PCB <sub>C</sub> (ND=1/2)	15	61,800	100	50,000	95UCL
	PCB <sub>C</sub> (ND=0)	15	61,800	100	50,000	95UCL
	TEQ <sub>P</sub> (ND=1/2)	15	1.9	100	0.824	95UCL
	TEQ <sub>P</sub> (ND=0)	15	0.787	100	0.442	95UCL
<b>Tissue – Edible Crab</b>						
FCA 1	TEQ(ND=1/2)	10	1.91	100	1.07	95UCL
	TEQ(ND=0)	10	1.85	100	0.972	95UCL
	PCB <sub>C</sub> (ND=1/2)	10	4,820	100	3,350	95UCL
	PCB <sub>C</sub> (ND=0)	10	4,740	100	3,290	95UCL
	TEQ <sub>P</sub> (ND=1/2)	10	0.234	100	0.148	95UCL
	TEQ <sub>P</sub> (ND=0)	10	0.0271	100	0.0201	95UCL
FCA 2/3	TEQ(ND=1/2)	20	0.558	60	0.286	95UCL
	TEQ(ND=0)	20	0.523	60	0.176	95UCL
	PCB <sub>C</sub> (ND=1/2)	20	11,400	100	7,170	95UCL
	PCB <sub>C</sub> (ND=0)	20	11,300	100	7,130	95UCL
	TEQ <sub>P</sub> (ND=1/2)	20	0.547	100	0.296	95UCL
	TEQ <sub>P</sub> (ND=0)	20	0.525	100	0.186	95UCL
<b>Soil</b>						
North of I-10	TEQ(ND=1/2)	46	153	100	22.6	95UCL
	TEQ(ND=0)	46	152	100	23.8	95UCL
	Aroclors(ND=1/2)	15	130,000	26.7	48,400	95UCL
	Aroclors(ND=0)	15	130,000	26.7	48,400	95UCL
	TEQ <sub>P</sub> (ND=1/2)	12	2.83	91.7	2.65	95UCL
	TEQ <sub>P</sub> (ND=0)	12	2.83	91.7	2.83	Max
Note: 95UCL – 95 percent upper confidence limit FCA – fish collection area Max – maximum result Max A 1254 – maximum result of Aroclor 1254 ND=0 – nondetect results assumed equal to zero in TEQ calculation ND=1/2 – nondetect results assumed equal to ½ the detection limit in TEQ calculation ng/kg – nanograms per kilogram PCB <sub>C</sub> – sum of 43 PCB congeners TEQ – 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalent TEQ <sub>P</sub> – toxicity equivalent for dioxin-like polychlorinated biphenyls						

## Exposure Assessment

Scenario Timeframe: Baseline						
Exposure Unit	Chemical of Concern	Number of Samples	Maximum Result (ng/kg)	Frequency of Detection (percent)	Exposure Point Concentration (ng/kg)	Statistical Measure
<b>Surface Soil</b>						
0-6 Inches	TEQ(ND=1/2)	26	36.9	100	27.9	95UCL
	TEQ(ND=0)	26	36.9	100	28.2	95UCL
<b>Surface and Shallow Subsurface Soil</b>						
0-12 Inches	TEQ(ND=1/2)	26	36.9	100	24.6	95UCL
	TEQ(ND=0)	26	36.9	100	24.7	95UCL
<b>Surface and Deep Subsurface Soils (0-10 Feet)</b>						
DS-1	TEQ(ND=1/2)	10	6,530	100	2,400	DWA
	TEQ(ND=0)	10	6,530	100	2,400	DWA
DS-2	TEQ(ND=1/2)	10	50,100	100	10,900	DWA
	TEQ(ND=0)	10	50,100	100	10,900	DWA
DS-3	TEQ(ND=1/2)	10	1,570	100	5.94	DWA
	TEQ(ND=0)	10	1,570	100	5.71	DWA
DS-4	TEQ(ND=1/2)	10	35,500	100	7,770	DWA
	TEQ(ND=0)	10	35,500	100	7,770	DWA
DS-5	TEQ(ND=1/2)	10	2,050	100	552	DWA
	TEQ(ND=0)	10	2,050	100	552	DWA
Note: -- - information unavailable DS- Deep Subsurface soil DWA – Depth-weighted average calculated as described in the BHHRA, page 6-1, Section 6.1.2.2.1, second paragraph and BHHRA Appendix M, page M-5, Section 3.1.1. ND=0 – nondetect results assumed equal to zero in TEQ calculation ND=1/2 – nondetect results assumed equal to ½ the detection limit in TEQ calculation ng/kg – nanograms per kilogram TEQ – 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalent						

Exposure pathways quantitatively evaluated in the BHHRA for the area north of I-10 and aquatic environment included the following:

- Recreational Fisher – direct contact (incidental ingestion and dermal contact) with sediment and soils, ingestion of finfish (represented by Hardhead catfish), and ingestion of shellfish (represented by blue crab and clam, *Rangia cuneata*)
- Subsistence Fisher – direct contact (incidental ingestion and dermal contact) with sediment and soils, ingestion of finfish (represented by Hardhead catfish), and ingestion of shellfish (represented by blue crab and clam, *Rangia cuneata*)
- Recreational Visitor – direct contact (incidental ingestion and dermal contact) with sediment and soils.

Exposure pathways for the area north of I-10 and aquatic environment are presented in the conceptual site model (Figure 12) and discussed in Section 5.1.1 of the BHHRA (Integral and Anchor, 2013b). Both recreational and subsistence fishers are assumed to ingest fish and/or shellfish caught at the site. It is assumed that 25 percent of the total fish or shellfish intake by recreational fishers is site-related (Table 20). Subsistence fishers are assumed to ingest 100 percent of total fish or shellfish intake that is site-related (Table 20). In the absence of detailed information regarding fishing activities and consumption patterns in the area, exposures were estimated using three scenarios: 1) ingestion of finfish only, 2) ingestion of clams only, and 3)

ingestion of crabs only. Assuming a single-tissue type exposure is a conservative approach because it identifies and quantifies potential exposure to the tissue type that may result in the highest potential for exposure (Integral and Anchor 2013b). Cumulative exposures (i.e., ingestion and dermal contact) were summed for each tissue ingestion scenario separately by exposure area. Baseline sediment, tissue, and soil exposure areas are presented on Figures 28 through 30, respectively. Table 21 provides a complete set of hypothetical exposure scenarios evaluated for the baseline condition. As a part of the BHHRA, the potential for adverse health effects to hypothetical receptors under conditions following the TCRA (termed as the post-TCRA condition) were also evaluated for dioxins and furans. As discussed in Section 2.2.5, TCRA construction was completed in 2011 and included installation of an armored cap, fencing, and warning signs over and around the northern impoundments. Post-TCRA sediment and soil exposure areas are presented on Figures 31 and 32. An incremental cancer risk greater than one in 10,000.

- A total endpoint-specific noncancer hazard index (HI) greater than 1.

Table 20 provides exposure parameter assumptions used for the area north of I-10 and the aquatic environment. The EPA based its remedy decision on the pre-TCRA hazards and risks.

Exposure pathways quantitatively evaluated in the BHHRA for the area south of I-10 included the following:

- Trespasser – direct contact (incidental ingestion and dermal contact) with surface soil
- Commercial Worker – direct contact (incidental ingestion and dermal contact) with surface and shallow subsurface soil
- Future Construction Worker – direct contact (incidental ingestion and dermal contact) with surface and subsurface soil.

Exposure pathways for the area south of I-10 are presented in the conceptual site model (Figure 14) and discussed in Section 6.1.1 of the BHHRA (Integral and Anchor 2013b). Exposure to future construction workers was evaluated using five 0.5-acre exposure units. Table 22 provides exposure parameter assumptions used for the area south of I-10.

The potential inhalation of dioxins and furans in air and exposure via direct contact with surface water were identified as minor exposure pathways and only addressed qualitatively. Inhalation exposure via vapor is considered minor because dioxins and furans are not volatile compounds and therefore would not tend to volatilize into air. Inhalation of particulates derived from the resuspension of surface soil may occur; however, this pathway generally contributes less than one percent of total estimated exposure when direct soil contact pathways (ingestion and dermal contact) are considered. Exposure to dioxins and furans in surface water is also considered to be a minor pathway because they are hydrophobic (not soluble in water), and tend to be bound to organic carbon in sediment. It is possible suspended sediment particles in the water column could come in contact with human receptors; however, those exposures are assumed to be brief and minimal because the movement of surface water would likely wash away the majority of sediment particles that contact the skin.

## Toxicity Assessment

The tables below provide the carcinogenic and noncarcinogenic risk information relevant to COCs in sediment, soil, and tissue that was used in the BHHRA (Integral and Anchor, 2013b).

### Cancer Toxicity Data

Chemical of Concern	Oral Cancer Slope Factor	Units	Source	Weight of Evidence/Cancer Guideline Description	Date of Most Recent Update
TEQ <sup>1</sup>	130,000	(mg/kg-day) <sup>-1</sup>	CalEPA	B2- probable human carcinogen, sufficient evidence in animals and inadequate or no evidence in humans	2011
Polychlorinated Biphenyls <sup>2</sup>	2.0	(mg/kg-day) <sup>-1</sup>	IRIS	B2- probable human carcinogen, sufficient evidence in animals and inadequate or no evidence in humans	1997

Note:

<sup>1</sup> 2,3,7,8-TCDD values were used to evaluate TEQ.

<sup>2</sup> Information presented was used in the reasonable maximum exposure calculations of the BHHRA, different values were used for central tendency exposure.

BHHRA – baseline human health risk assessment

mg/kg – milligrams per kilogram

TCDD – tetrachlorodibenzo-p-dioxin

TEQ – 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalent

### Noncancer Toxicity Data

Chemical of Concern	Chronic			Subchronic			Primary Target Organ	Date of Most Recent Update
	Oral RfD Value (pg/kg-day)	Source	Combined Uncertainty/Modifying Factors	Oral RfD Value (pg/kg-day)	Source	Combined Uncertainty/Modifying Factors		
TEQ <sup>1</sup>	0.7	IRIS	30	0.7	IRIS <sup>2</sup>	30	Reproductive/Developmental Issues	2/17/2012
Polychlorinated Biphenyls <sup>3</sup>	20,000	IRIS	300	60,000	calculated <sup>4</sup>	100	Immune System	11/1/1996

Note:

<sup>1</sup> 2,3,7,8-TCDD values were used to evaluate TEQ.

<sup>2</sup> no subchronic RfD was available, the chronic RfD was selected.

<sup>3</sup> Values for Aroclor 1254 presented. Aroclor 1254 was the only Aroclor detected at the site.

<sup>4</sup> Derivation of the chronic RfD included a factor adjust for less than lifetime exposure. This value was removed to derive the subchronic exposure.

IRIS – Integrated Risk Information System

pg/kg – picograms per kilogram

RfD – reference dose

TCDD – tetrachlorodibenzo-p-dioxin

TEQ – 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalent

## Risk Characterization

For carcinogens, risks are generally expressed as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the carcinogen. Excess lifetime cancer risk is calculated from the following equation:

$$\text{Risk} = \text{CDI} \times \text{SF}$$

where

risk = a unitless probability (e.g.,  $2 \times 10^{-5}$ ) of an individual developing cancer as a result of site-related exposure

CDI = chronic daily intake averaged over 70 years (picograms per kilogram [pg/kg]-day)

SF = slope factor, expressed as (pg/kg-day)<sup>-1</sup>.

These risks are probabilities that usually are expressed in scientific notation (e.g.,  $1 \times 10^{-6}$ ). An excess lifetime cancer risk of  $1 \times 10^{-6}$  indicates that an individual has a 1 in 1,000,000 chance of developing cancer as a result of site-related exposure. This is referred to as an “excess lifetime cancer risk” because it would be in addition to the risks of cancer individuals face from other causes such as smoking or exposure to too much sun. According to the American Cancer Society, the chance of an individual developing cancer from other causes has been estimated to be as high as one in three for females and one in two for males EPA’s generally acceptable risk range for site-related exposures is  $10^{-4}$  to  $10^{-6}$ .

The potential for noncarcinogenic effects is evaluated by comparing an exposure level over a specified time period (e.g., life-time) with a reference dose (RfD) derived for a similar exposure period. An RfD represents a level that an individual may be exposed to that is not expected to cause any deleterious effect. The ratio of exposure to toxicity is called a hazard quotient (HQ). An  $HQ < 1$  indicates that a receptor’s dose of a single contaminant is less than the RfD, and that toxic noncarcinogenic effects from that chemical are unlikely. The hazard index (HI) is generated by adding the HQs for all COCs that affect the same target organ (e.g., liver) or that act through the same mechanism of action within a medium or across all media to which a given individual may reasonably be exposed. An  $HI < 1$  indicates that, based on the sum of all HQs from different contaminants and exposure routes, toxic noncarcinogenic effects from contaminants are unlikely. An  $HI \geq 1$  indicates that site-related exposures may present a risk to human health.

The HQ is calculated as follows:

$$\text{Non-cancer HQ} = \text{CDI/RfD}$$

Where:

CDI = chronic daily intake

RfD = reference dose.

CDI and RfD are expressed in the same units and represent the same exposure period (i.e., chronic, subchronic, or short-term).

The excess lifetime cancer risk to a recreational fisher from direct exposure to sediment through the inadvertent ingestion and dermal contact and indirect exposure to sediment through the ingestion of fish/shellfish routes of intake was estimated for Beach Area E at  $7.0 \times 10^{-4}$ , which is greater than the upper end of the EPA’s generally accepted excess cancer risk range of  $1 \times 10^{-4}$ . The other Beach Areas (Beach Area A, B/C, and D) had excess cancer risk less than the lower end of the EPA generally accepted risk range of  $1 \times 10^{-6}$  (Khoury, 2016). Cancer risk was estimated using CalEPA tier 3 toxicity value or cancer slope factor of  $1.3 \times 10^5$  (mg/kg-day)<sup>-1</sup>. Tier 3 toxicity values usually do not go through rigorous review as EPA tier 1 toxicity values; using current tier 3 toxicity values for protecting human health at dioxin levels associated with  $10^{-4}$  excess cancer risk effects will not be protective for non-cancer adverse health effects at a HI of 1. Therefore, EPA relied on the tier 1 non-cancer risk toxicity value in its human health risk

assessment and in determining cleanup levels for the site, but not the cancer risk. EPA's rationale that cleaning down to the noncancer effects level will also be protective at the midlevel for the EPA's acceptable excess cancer risk range.

The text and tables below provide a summary of site related noncancer HIs above 1 identified in the BHHRA (Integral and Anchor 2013b). HIs presented below are based on calculations of reasonable maximum exposure. Reasonable maximum exposure is defined as the highest exposure that could be reasonably anticipated to occur for a given exposure pathway and scenario at the site. Central tendency exposure, or the average estimate of exposure, was also evaluated in the BHHRA (Integral and Anchor 2013b); however, it will not be included here for brevity.

The deterministic risk assessment for a recreational fisher north of I-10 and the aquatic environment is presented in Section 5.2.2.1 of the BHHRA (Integral and Anchor, 2013b) and is summarized below. For a recreational fisher in Exposure Scenarios 3A, 3B, and 3C (direct exposure to Beach Area E and the ingestion of catfish, clam, or crab from the fishing areas identified), the reproductive/developmental noncancer HIs are greater than one and indicate a potential for adverse noncancer effects. The table below provides noncancer HQs for exposure to sediment and fish or shellfish for all scenarios, with endpoint-specific HIs greater than one for recreational fisher exposure scenarios.

Scenario Timeframe:	Baseline				
Receptor Population:	Recreational Fisher				
Receptor Age:	Young Child				
Calculation Assumption:	Reasonable Maximum Exposure				
Chemical <sup>1</sup>	Primary Target Organ	Noncancer Hazard Quotient			Exposure Route Total <sup>3</sup>
		Incidental Ingestion of Sediment	Dermal Contact with Sediment	Consumption of Fish or Shellfish <sup>2</sup>	
Scenario 1A: Direct Exposure Beach Area A; Ingestion of Catfish from FCA 2/3					
TEQ	Reproductive/Developmental	0.00023	0.0013	1.1	1.1
Reproductive/Developmental Endpoint-Specific Hazard Index					1.1
Scenario 2A: Direct Exposure Beach Area B/C; Ingestion of Catfish from FCA 2/3					
TEQ	Reproductive/Developmental	0.0032	0.018	1.1	1.1
Methylmercury <sup>4</sup>	Reproductive/Developmental	--	--	0.27	0.27
Reproductive/Developmental Endpoint-Specific Hazard Index					1.1
Scenario 3A: Direct Exposure Beach Area E; Ingestion of Catfish from FCA 2/3					
TEQ	Reproductive/Developmental	6.5	37	1.1	45
Methylmercury <sup>4</sup>	Reproductive/Developmental	--	--	0.27	0.27
Reproductive/Developmental Endpoint-Specific Hazard Index					45
PCBs	Immune	0.049	0.65	0.88	1.6
Immune Endpoint-Specific Hazard Index					1.6
Scenario 3B: Direct Exposure Beach Area E; Ingestion of Clam from FCA 2					
TEQ	Reproductive/Developmental	6.5	37	0.21	44
Reproductive/Developmental Endpoint-Specific Hazard Index					44
Scenario 3C: Direct Exposure Beach Area E; Ingestion of Crab from FCA 2/3					
TEQ	Reproductive/Developmental	6.5	37	0.0032	44
Reproductive/Developmental Endpoint-Specific Hazard Index					44
Scenario 4A: Direct Exposure Beach Area D; Ingestion of Catfish from FCA 1					
TEQ	Reproductive/Developmental	0.0011	0.006	1.0	1.0
Reproductive/Developmental Endpoint-Specific Hazard Index					1.0
Note:					

Numbers in Bold represent an HQ>1 or an HI>1.

<sup>1</sup> All chemicals with primary target organ exposure route totals greater than 1 are included in this table.

<sup>2</sup> See scenario title for identification of tissue consumed

<sup>3</sup> Two significant figures presented, differences between values presented in the risk assessment tables and those presented here are either a result of the number of significant figures presented, rounding, or both.

FCA – fish collection area

PCB – polychlorinated biphenyls

TEQ – 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalent

### North of I-10 and the Aquatic Environment Noncancer Hazards for a Recreational Fisher

The deterministic risk assessment for a recreational fisher north of I-10 and the aquatic environment is presented in Section 5.2.2.1 of the BHHRA (Integral and Anchor 2013b) and is summarized below[[[ for a recreational fisher in Exposure Scenarios 3A, 3B, and 3C (direct exposure to Beach Area E and the ingestion catfish, clam, or crab from the fishing areas identified)]]].

The deterministic risk assessment for a subsistence fisher north of I-10 and the aquatic environment is presented in Section 5.2.2.2 of the BHHRA (Integral and Anchor 2013b) and is summarized below. For a subsistence fisher exposure to any of the beaches and the ingestion catfish, clam, or crab from the fishing areas identified have reproductive/developmental noncancer HIs greater than one and indicate a potential for adverse noncancer effects. The table below provides noncancer HQs for exposure to sediment and fish or shellfish for all scenarios with endpoint-specific HIs greater than one for subsistence fisher exposure scenarios.

### North of I-10 and the Aquatic Environment Noncancer Hazards for a Subsistence Fisher

Scenario Timeframe:	Baseline				
Receptor Population:	Subsistence Fisher				
Receptor Age:	Young Child				
Calculation Assumption:	Reasonable Maximum Exposure				
Chemical <sup>1</sup>	Primary Target Organ	Noncancer Hazard Quotient			Exposure Route Total <sup>3</sup>
		Incidental Ingestion of Sediment	Dermal Contact with Sediment	Consumption of Fish or Shellfish <sup>2</sup>	
Scenario 1A: Direct Exposure Beach Area A; Ingestion of Catfish from FCA 2/3					
TEQ	Reproductive/Developmental	0.00061	0.0035	9.2	9.2
Reproductive/Developmental Endpoint-Specific Hazard Index					9.2
PCBs	Immune	--	--	7.4	7.4
Immune Endpoint-Specific Hazard Index					7.4
Scenario 2A: Direct Exposure Beach Area B/C; Ingestion of Catfish from FCA 2/3					
TEQ	Reproductive/Developmental	0.0085	0.048	9.2	9.2
Reproductive/Developmental Endpoint-Specific Hazard Index					9.2
PCBs	Immune	--	--	7.4	7.4
Immune Endpoint-Specific Hazard Index					7.4

**North of I-10 and the Aquatic Environment Noncancer Hazards for a Subsistence Fisher  
(Continued)**

Scenario Timeframe:

Receptor Population:

Receptor Age:

Calculation Assumption:

Baseline

Subsistence Fisher

Young Child

Reasonable Maximum Exposure

Chemical<sup>1</sup>

Primary Target Organ

Noncancer Hazard Quotient

Incidental Ingestion of Sediment

Dermal Contact with Sediment

Consumption of Fish or Shellfish<sup>2</sup>

Exposure Route Total<sup>3</sup>

Scenario 2B: Direct Exposure Beach Area B/C; Ingestion of Clam from FCA 2

TEQ

Reproductive/Developmental

0.0085

0.048

2.9

2.9

Reproductive/Developmental Endpoint-Specific Hazard Index

2.9

Scenario 3A: Direct Exposure Beach Area E; Ingestion of Catfish from FCA 2/3

TEQ

Reproductive/Developmental

17

99

9.2

130

Reproductive/Developmental Endpoint-Specific Hazard Index

130

PCBs

Immune

0.13

1.7

7.4

9.2

Immune Endpoint-Specific Hazard Index

9.2

Scenario 3B: Direct Exposure Beach Area E; Ingestion of Clam from FCA 2

TEQ

Reproductive/Developmental

17

99

2.9

120

Reproductive/Developmental Endpoint-Specific Hazard Index

120

PCBs

Immune

0.13

1.7

0.26

2.1

Immune Endpoint-Specific Hazard Index

2.1

Scenario 3C: Direct Exposure Beach Area E; Ingestion of Crab from FCA 2/3

TEQ

Reproductive/Developmental

17

99

0.043

120

Reproductive/Developmental Endpoint-Specific Hazard Index

120

PCBs

Immune

0.13

1.7

0.038

1.9

Immune Endpoint-Specific Hazard Index

1.9

Scenario 4A: Direct Exposure Beach Area D; Ingestion of Catfish from FCA 1

TEQ

Reproductive/Developmental

0.0028

0.016

8.8

8.9

Reproductive/Developmental Endpoint-Specific Hazard Index

8.9

PCBs

Immune

--

--

8.2

8.2

Immune Endpoint-Specific Hazard Index

8.2

Note:

Numbers in Bold represent an HQ>1 or an HI>1.

<sup>1</sup> All chemicals with primary target organ exposure route totals greater than 1 are included in this table.

<sup>2</sup> See scenario title for identification of tissue consumed

<sup>3</sup> Two significant figures presented, differences between values presented in the risk assessment tables and those presented here are either a result of the number of significant figures presented, rounding, or both.

FCA – fish collection area

PCB – polychlorinated biphenyls

TEQ – 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalent

The deterministic risk assessment for a recreational visitor north of I-10 and the aquatic environment is presented in Section 5.2.2.3 of the BHHRA (Integral and Anchor 2013b) and is summarized below. For a recreational visitor in Exposure Scenario 3 (direct exposure to Beach Area E), the reproductive/developmental noncancer HI is greater than one and indicates there is a potential for adverse noncancer effects. The table below provides noncancer HQs for exposure to sediment and soil for all scenarios with endpoint-specific HIs greater than one for recreational fisher exposure scenarios.

<b>Scenario Timeframe:</b>	Baseline		
<b>Receptor Population:</b>	Recreational Visitor		
<b>Receptor Age:</b>	Young Child		
<b>Calculation Assumption:</b>	Reasonable Maximum Exposure		
Chemical <sup>1</sup>	Primary	Noncancer Hazard Quotient	Total <sup>2</sup>

	Target Organ	Incidental Ingestion of Sediment	Incidental Ingestion of Soil	Dermal Contact with Sediment	Dermal Contact with Soil	
<b>Scenario 3: Direct Exposure Beach Area E</b>						
TEQ	Reproductive/Developmental	8.7	0.015	49	0.0021	58
<b>Reproductive/Developmental Endpoint-Specific Hazard Index</b>						<b>58</b>
Note: <sup>1</sup> All chemicals with primary target organ exposure route totals greater than 1 are included in this table. <sup>2</sup> Two significant figures presented, differences between values presented in the risk assessment tables and those presented here are either a result of the number of significant figures presented, rounding, or both. TEQ – 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalent quotient						

### North of I-10 and the Aquatic Environment Noncancer Hazards for a Recreational Visitor

Following completion of the deterministic risk assessment, results of which are presented above, refinement analyses were completed if north of I-10 and the aquatic environment exposure scenarios met one or both of the following thresholds:

- An incremental cancer risk greater than one in 10,000.
- A total endpoint-specific noncancer HI greater than 1

Refinement analyses are discussed in Section 5.2.3 of the BHHRA (Integral and Anchor, 2013b) and included: 1) an analysis and comparison of background hazards with estimated deterministic hazards for the area, 2) an evaluation of post-TCRA condition hazards, and 3) a probabilistic risk assessment of potential hazards.

The background hazard evaluation is presented in Section 5.2.3.1 of the BHHRA (Integral and Anchor, 2013b), the results of which are summarized below. The tables below provide summaries of noncancer and TEQ cancer HIs for recreational fisher, subsistence fisher, and recreational visitor exposure scenarios, respectively. Evaluation of background hazards, performed in the BHHRA, indicated the following:

- Sediment
  - Exposure to beach area E through the ingestion and dermal routes of intake resulted in hazards exceeding background.
  - Exposure to other beach areas results in hazards consistent with background
- Catfish
  - Ingestion of catfish from FCA 1 and FCA 2/3 resulted in hazards exceeding background
  - Background hazards contribute to total hazards (e.g., provide almost ½ the total hazards for PCBs and TEQ)
- Clams
  - Ingestion of clams from FCA 2 results in hazards exceeding background
  - Ingestion of clams from FCA 1/3 results in hazards slightly higher than background.

**Recreational Fisher Summary of Background Hazards**

Scenario	Incidental Ingestion of Sediment	Dermal Contact with Sediment	Fish or Shellfish Ingestion	Hazard Index Total <sup>1</sup>
<b>Noncancer Hazard Index</b>				
A – Direct Exposure to Sediment; Ingestion of Catfish	0.002	0.01	<b>1</b>	<b>1</b>
B – Direct Exposure to Sediment; Ingestion of Clam	0.002	0.01	0.01	0.03
C – Direct Exposure to Sediment; Ingestion of Crab	0.002	0.01	0.01	0.03
Note: Numbers in Bold represent an HI>1. <sup>1</sup> Calculations based on reasonable maximum exposure. TEQ – 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalent				

**Subsistence Fisher Summary of Background Hazards**

Scenario	Incidental Ingestion of Sediment	Dermal Contact with Sediment	Fish or Shellfish Ingestion	Hazard Index Total <sup>1</sup>
<b>Noncancer Hazard Index</b>				
A – Direct Exposure to Sediment; Ingestion of Catfish	0.005	0.04	<b>10</b>	<b>10</b>
B – Direct Exposure to Sediment; Ingestion of Clam	0.005	0.04	0.2	0.2
C – Direct Exposure to Sediment; Ingestion of Crab	0.005	0.04	0.1	0.2
Note: Numbers in Bold represent an HI>1. <sup>1</sup> Calculations based on reasonable maximum exposure. TEQ – 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalent				

**Recreational Visitor Summary of Background Hazards**

Scenario	Incidental Ingestion of Sediment	Incidental Ingestion of Soil	Dermal Contact with Sediment	Dermal Contact with Soil	Hazard Index Total <sup>1</sup>
<b>Noncancer Hazard Index</b>					
Direct Exposure to Sediment and Soil	0.002	0.01	0.02	0.003	0.04
Note: <sup>1</sup> Calculations based on reasonable maximum exposure. TEQ – 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalent					

The probabilistic risk assessment is presented in Section 5.2.3.3 of the BHHRA (Integral and Anchor, 2013b); the results of which are summarized below. The probabilistic risk assessment modeled exposure for young child fishers and young child recreational visitors for exposure to TEQ in sediment, tissue, and soils, PCBs in all tissue types, and methylmercury in catfish. Appendix G of the BHHRA (Integral and Anchor, 2013b) provides a complete presentation of the probabilistic risk assessment. The tables below present the deterministic and probabilistic results for noncancer. The results provide insight into the variability of exposures and hazards that may occur. Variability in various factors that influence exposure has a large impact on estimated hazards. Because the reasonable maximum exposure for a young child did not account for these sources of variability, they likely overestimated hazards (Integral and Anchor, 2013b).

### Probabilistic Results for Noncancer Hazards, Area North of I-10 and Aquatic Environment

Scenario	Endpoint Category	Hazard Index			
		Deterministic Results <sup>1</sup>		Probabilistic Results	
		Recreational	Subsistence	90 <sup>th</sup> Percentile	95 <sup>th</sup> Percentile
BASELINE HAZARDS					
Fisher Scenarios (Direct Contact / Tissue Ingestion)					
1A – Beach A / Catfish FCA 2/3	Immunotoxicity	0.9	7	2	3
	Reproductive/Developmental	1	10	2	3
2A – Beach B/C / Catfish FCA 2/3	Immunotoxicity	0.9	7	2	3
	Reproductive/Developmental	1	10	2	3
3A – Beach E / Catfish FCA 2/3	Immunotoxicity	2	9	2	3
	Reproductive/Developmental	40	100	8	10
4A – Beach D / Catfish FCA 1	Immunotoxicity	1	8	2	3
	Reproductive/Developmental	1	10	2	4
2B – Beach B/C / Clam FCA 2	Immunotoxicity	0.02	0.3	0	0.07
	Reproductive/Developmental	0.2	3	0.03	0.3
3B – Beach E / Clam FCA 2	Immunotoxicity	0.7	2	0	0.07
	Reproductive/Developmental	40	100	6	10
3C – Beach E / Crab FCA 2/3	Immunotoxicity	0.7	2	0	0.01
	Reproductive/Developmental	40	100	6	10
Visitor Scenario (Direct Contact)					
3 – Beach E and Soil North of I-10	Reproductive/Developmental	60	--	2	4
BACKGROUND HAZARDS					
Fisher Scenarios (Direct Contact / Tissue Ingestion)					
A – Direct Exposure to Sediment; Ingestion of Catfish	Immunotoxicity	0.5	4	1	2
	Reproductive/Developmental	0.7	6	1	2
B – Direct Exposure to Sediment; Ingestion of Clam	Immunotoxicity	0.005	0.06	0	0.03
	Reproductive/Developmental	0.008	0.08	0.003	0.03
C – Direct Exposure to Sediment; Ingestion of Crab	Immunotoxicity	0.0004	0.006	0	0.003
	Reproductive/Developmental	0.006	0.06	0.003	0.02
Visitor Scenario (Direct Contact)					
Direct Exposure to Sediment and Soil	Reproductive/Developmental	0.009	--	0.0009	0.001
Note: Numbers in Bold represent an HI>1. <sup>1</sup> Calculations based on reasonable maximum exposure. FCA – fish collection area TCRA – time critical removal action TEQ – 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalent					

The human health risk assessment summary and conclusions for the area south of I-10 is presented in Section 6.2.4 of the BHHRA (Integral and Anchor, 2013b) and is summarized below. For the area south of I-10, the future construction worker TEQ noncancer HIs -----are greater than one for exposure areas DS-1, DS-2, and DS-4. The tables below provide endpoint-specific HIs and cumulative noncancer HIs for future construction worker exposure scenarios that have a noncancer HI greater than one.

**South of I-10 Noncancer Hazards for a Future Construction Worker**

Scenario Timeframe:	Baseline			
Receptor Population:	Construction Worker			
Receptor Age:	Adult			
Calculation Assumption:	Reasonable Maximum Exposure			
Chemical <sup>1</sup>	Primary Target Organ	Noncancer Hazard Quotient		Total <sup>2</sup>
		Incidental Ingestion of Soil	Dermal Contact with Soil	
Scenario DS-1: Direct Exposure to Surface and Subsurface Soils				
TEQ	Reproductive/Developmental	4.8	0.49	5.3
Reproductive/Developmental Endpoint-Specific Hazard Index				5.3
Scenario DS-2: Direct Exposure to Surface and Subsurface Soils				
TEQ	Reproductive/Developmental	22	2.2	24
Reproductive/Developmental Endpoint-Specific Hazard Index				24
Scenario DS-4: Direct Exposure to Surface and Subsurface Soils				
TEQ	Reproductive/Developmental	16	1.6	17
Reproductive/Developmental Endpoint-Specific Hazard Index				17
Note:				
Numbers in Bold represent an HQ>1 or an HI>1.				
<sup>1</sup> All chemicals with primary target organ exposure route totals greater than 1 are included in this table.				
<sup>2</sup> Two significant figures presented, differences between values presented in the risk assessment tables and those presented here are either a result of the number of significant figures presented, rounding, or both.				
TEQ – 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalent				

The BHHRA identifies the following as sources contributing to risk assessment uncertainty in Sections 5.2.4 and 6.2.3:

- Data collection, analysis, and treatment (e.g., elevated detection limits for PCBs as Aroclors, analysis of 43 PCB congeners rather than the complete set of 209)
- Calculation of dioxin and furan TEQs (e.g., use of ½ the detection limit for nondetect congeners)
- Exposure assessment assumptions (e.g., the lack of quantification of minor pathways, age assumptions, fish and shellfish consumption rates)
- Toxicity criteria (e.g., dioxins and furans, PCBs).

However, the BHHRA also states that “the parameters used for evaluating potential exposures and estimating risks and hazards relied on multiple conservative assumptions, which enhance the likelihood that potential assumed exposures and estimated risks are overestimated” (Integral and Anchor 2013b).

The USEPA developed its own risk assessment to augment the BHHRA and support a comprehensive cleanup level for the site. It did so in a Memorandum dated August 29, 2016 (Khoury, 2016a). An exposure scenario for a hypothetical recreational young child fisher for potential noncancer effects was evaluated for dioxin and dioxin like compounds. For potential cancer effects of dioxin, an exposure scenario for a hypothetical adult fisher was evaluated who was exposed to dioxin in sediments for the first six years of his life as a child and the remaining 20 years of life exposed as an adult. Exposure through the ingestion and dermal contact with

sediment and through the ingestion of fish/shellfish was evaluated for both scenarios. The noncancer risk to a recreational child fisher from exposure to sediment through the ingestion and dermal routes of intake was calculated for Beach Area E at a hazard index of 63, which is greater than the EPA acceptable level of a HI of one. The excess cancer risk for an adult fisher exposed to sediment through the ingestion and dermal routes of intake was estimated at  $6.6 \times 10^{-4}$  which is greater than the upper end of the EPA's generally accepted excess cancer risk range of  $1 \times 10^{-4}$ . The other beach areas (Beach Area A, B/C, and D) had levels lower than the EPA acceptable HI of one and a cancer risk less than the lower end of the acceptable cancer risk range of  $1 \times 10^{-6}$ .

The risk to a hypothetical recreational young child fisher from ingestion of fish and shellfish at fish collection area (FCA) 1 and combined fish collection areas 2 and 3 (FCA2/3) was estimated at a HI of 1.8 for each of the fish collection areas, which is higher than the EPA acceptable level of a HI of one. Most of the noncancer risk was due to ingestion of Hardhead catfish fillet which was used as a conservative representative of finfish ingestion. Catfish are bottom feeders and would come in contact with the sediment more often than other finfish. Ingestion of shellfish (edible crab and clam) was found to be acceptable if ingested at the rate used in the calculations (i.e. 600 mg/day for a child and 2,000 mg/day for an adult).

All exposure input parameters used in the baseline human health risk assessment (Table 5-8 in Integral and Anchor, 2013b) were used in EPA's addendum risk assessment for a young recreational fisher. The only changes EPA made were for the body weight of a child, lowered from 19 Kg to 15 Kg, and the averaging time was changed from 78 years to 70 years to be consistent with EPA national guidance.

Studies done to develop site specific biota-sediment accumulation factor (BSAF) to correlate sediment concentration to fish tissue concentration failed to come up with a reliable, defensible number. In the absence of a reliable BSAF value for fish, EPA used the default BSAF value provided in the US EPA Combustion Guidance in order to be able to develop a sediment cleanup number for the site.

The USEPA suggests that, along with ethnic characteristics and cultural practices of an area's population, the poverty rate could contribute to any determination of the rate of subsistence fishing in an area. The USEPA and the TDSHS find it is important to consider subsistence fishing as occurring at any water body because subsistence fishers (as well as recreational anglers and certain tribal and ethnic groups) usually consume more locally caught fish than the general population. These groups sometimes harvest fish or shellfish from the same water body over many years to supplement caloric and protein intake. People who routinely eat fish from chemically contaminated water bodies or those who eat large quantities of fish from the same waters could increase their risk of adverse health effects. The USEPA suggests that states assume that at least 10% of licensed fisherman in any area are subsistence fishers. Subsistence fishing, while not explicitly documented by the TDSHS, likely occurs in Texas. The TDSHS assumes the rate of subsistence fishing to be similar to that estimated by the USEPA.

In the TDSHS Public Health Assessment that was released in October 2012, one of the exposure scenarios was that of a subsistence fisherman. This was incorporated by EPA to account for the potential

exposure pathway to children and adults that may be subsistence fishermen and consume fish caught from areas surrounding the SJRWP. The scenario used was: adults who fish 260 days/year for 30 years and children of subsistence fishers who are exposed from age 3 – 50 (child becomes a subsistence fisherman in adult years (TDSHS, 2012).

Through TDSHS outreach activities, most of the people interviewed along the San Jacinto River, Houston Ship Channel, and Upper Galveston Bay have told TDSHS that they are fishing and/or crabbing for recreational purposes; however, some people do admit to consuming fish and/or crabs from these areas. Given the general lack of predictability of subsistence behaviors based on demographic characteristics, and the very low likelihood that long-term subsistence fishing is occurring within USEPA's Preliminary Site Perimeter (TDSHS 2012), the subsistence fisher, as evaluated in this BHHRA, is hypothetical and unlikely to have been present or to be present in the future in the area under study.

A cleanup level for the protection of the most sensitive and vulnerable segment of the exposed population was developed for the northern impoundments and sediments. A young hypothetical recreational fisher was assumed to be exposed to dioxin and dioxin like compounds in sediment through the inadvertent ingestion and dermal contact with contaminated sediment for an exposure frequency of 39 days/year for 6 years. The same young recreational fisher is also expected to eat fish/shellfish collected from areas with contaminated sediment. The total cleanup level for the site was estimated at 30 ng/Kg for dioxin TEQs associated with a HI of 1. The total excess cancer risk associated with a sediment concentration of 30 ng/Kg is estimated at  $2.1 \times 10^{-5}$ . By protecting the health of a young recreational fisher, this cleanup level is also protecting the health of a recreational adult fisher.

### **2.7.2 Summary of Ecological Risk Assessment**

A screening level ecological risk assessment (SLERA) for the site, not addressing the southern impoundment, was completed in 2010. The initial SLERA is included as Appendix B to the RI/FS Work Plan (Anchor and Integral, 2010). Following completion of the SLERA, a BERA for the site, not addressing the southern impoundment, was completed (Integral, 2013). A SLERA for the southern impoundment was completed concurrently with the site BERA and is included as Appendix E to the BERA (Integral, 2013). A BERA for the southern impoundment was subsequently completed and is included as Appendix D to the RI Report (Integral and Anchor, 2013a).

### **Identification of Chemicals of Potential Ecological Concern**

The BERA for the area north of I-10 and aquatic environments identified chemicals of potential ecological concern (COPECs). Tables 23 and 24 present the COPEC screening. Chemicals in sediment with a detection frequency of at least 5 percent in the RI dataset that were either 1) present in at least one sample at a concentration greater than sediment screening concentrations protective of benthic invertebrate communities or 2) have no screening value protective of benthic invertebrate communities and were not correlated with dioxins and furans, are considered COPECs for benthic macroinvertebrate communities (Integral, 2013). If a chemical was detected in greater than 5 percent of sediment samples in the RI dataset, and is thought to be

bioaccumulative (TCEQ, 2006), it was considered to be a COPEC and was evaluated for risk to fish and wildlife (Integral, 2013).

## Exposure Assessment

The site is located in a low gradient, tidal estuary near the confluence of the San Jacinto River and the Houston Ship Channel, as discussed above in Section 2.5 of this ROD. Habitats include upland, aquatic, and riparian.

There are no site-specific data describing wildlife uses of the upland portions of the site. Based on local wildlife lists and the types of habitat and land uses, it is reasonable to expect a suite of generalist terrestrial species that are not highly specialized in their habitat requirements and are adapted to moderate levels of disturbance. The reptiles and amphibians that could occur in the vicinity of the site include snakes, alligators, and turtles. Avian taxa using upland habitats may include sparrows and other generalist passerines, starlings, pigeons and doves, corvids, and killdeer. Mammals expected in a semi-urban environment like the site include small mammals (rodents), skunks, raccoons, coyotes, and opossums. Upland habitats could support mammals, such as marsh rice rats and deer that could migrate to the islands close to mainland areas, as well as passerines that could use the vegetated uplands for nesting and foraging, and shoreline birds such as sandpipers and herons that could wade and forage in the shallow areas adjacent to the islands.

The tidal portions of the San Jacinto River and upper Galveston Bay provide rearing, spawning, and adult habitat for a variety of marine and estuarine fish and invertebrate species. Species known to occur in the vicinity of the site include clams and oysters, blue crab (*Callinectes sapidus*), black drum (*Pagrus cromis*), southern flounder (*Paralichthys lethostigma*), hardhead catfish (*Ariopsis afelis*), blue catfish (*Ictalurus furcatus*), spotted sea trout (*Cynoscion nebulosus*), and grass shrimp (*Palaemonetes pugio*) (Gardiner et al., 2008; Usenko et al., 2009).

Aquatic birds and semiaquatic mammals that are found in the vicinity of the site include ducks, shorebirds, wading birds (herons and egrets), diving piscivores, and various others. There are a number of migratory bird species known to winter in the vicinity of the site. They include belted kingfisher (*Megasceryle alcyon*), red breasted merganser (*Mergus serrator*), greater yellowlegs (*Tringa melanoleuca*), western sandpiper (*Calidris mauri*), and dabbling ducks including gadwall (*Anas strepera*) and teal. Herons and closely related birds that use wetland and estuarine habitats and that may be present in the site vicinity include the green (*Butorides virescens*), tri-colored (*Egretta tricolor*), and little blue (*E. cerulea*) herons, and also the black-crowned (*Nycticorax nycticorax*) and yellow-crowned (*N. violacea*) night-herons.

Raptors, rails, pelicans, gulls, ducks, and sandpipers are also among the aquatic-dependent and aquatic-associated bird species that use the aquatic habitat that is present in the vicinity of the site. Sandpipers, egrets, and herons are wading birds that forage along shallow intertidal areas for benthic macroinvertebrates and small fish. Piscivorous bird species that may forage in the open waters of the river include cormorants, osprey, and pelicans. Omnivores including gulls and ducks may forage at the river's edge as well as in the water column. Mammals using both aquatic and wetland habitats that could occur in the vicinity of the site include the marsh rice rat, muskrats, nutria, and raccoon.

### **Endangered and Threatened Species**

Wildlife that are state-listed as threatened and endangered and have the potential to be found in the general vicinity of the site are:

- Timber rattlesnake
- Smooth green snake
- Alligator snapping turtle
- White-faced ibis
- Brown pelican
- Rafinesque's big-eared bat.

In addition to these listed species, the American bald eagle, protected under the federal Bald and Golden Eagle Protection Act and listed as threatened by the State of Texas, may be found in the vicinity of the site.

### **Ecological Receptors and Receptor Surrogates**

Ecological receptor surrogates were selected to be representative of the trophic and ecological relationships known or expected at the site. In selecting receptor surrogates, the following criteria were considered:

- The receptor is or could potentially be present at the site.
- The receptor is representative of one or more feeding guilds.
- The receptor is known to be either sensitive or potentially highly exposed to COPECs at the site.
- Life history information is available in the literature or is available for a similar species that can be used to inform life history parameters for the receptor.

Tables 25 and 26 provide receptors used in the north of I-10 and south of I-10 BERAs, respectively. Tables 27 and 28 provide assessment endpoints, lines of evidence, and measurement of exposure for the area north of I-10 and aquatic environment, and the area south of I-10, respectively.

### **Ecological Risk Characterization**

The table below presents a summary of baseline ecological risks identified in the BERA (Integral, 2013) for the area north of I-10 and aquatic environment.

**Summary of Baseline Ecological Risks for the Area North of I-10 and Aquatic Environment**

Receptor of Concern	Feeding Guild	Chemical of Concern	Baseline Risk Identified <sup>1</sup>
<b>Benthic Macroinvertebrates</b>			
Mollusks	Filter feeders	2,3,7,8-TCDD	Reproductive risks to mollusks (primarily in the area which surrounds the waste impoundments)
Individual mollusks	Filter feeders	2,3,7,8-TCDD	Low risks of reproductive effects (sediments adjacent to the upland sand separation area)
<b>Birds</b>			
Spotted sandpiper	Invertivore (probing)	Dioxins and furans	Moderate risks to individual birds, low risk to populations
Killdeer	Invertivore (terrestrial)	Dioxins and furans	Moderate risks to individual birds, low risk to populations
Killdeer	Invertivore (terrestrial)	Zinc	Low to negligible risk to populations
<b>Mammals</b>			
Marsh rice rat	Omnivore	TEQ <sub>M</sub>	Risk to individual small mammals with home ranges that include areas adjacent to the impoundments, low to negligible risk to populations
Note: <sup>1</sup> Risk to individuals of characterized as negligible are not included in this table. 2,3,7,8-TCDD – 2,3,7,8-tetrachlorodibenzo-p-dioxin Dioxins – polychlorinated dibenzo-p-dioxins Furans – polychlorinated dibenzofurans TEQ <sub>M</sub> – toxicity equivalent for 2,3,7,8-tetrachlorodibenzo-p-dioxin calculated using toxicity equivalent factors for mammals			

The table below presents a summary of baseline ecological risks identified in the BERA (Integral and Anchor, 2013a) for the area south of I-10.

**Summary of Baseline Ecological Risks for the Area South of I-10**

Receptor of Concern	Feeding Guild	Chemical of Concern	Baseline Risk Identified <sup>1</sup>
<b>Birds</b>			
Terrestrial birds	--	Cadmium Chromium Copper	Low to negligible risks to the assessment endpoint of stable or increasing populations
Killdeer	Invertivore (terrestrial)	Lead Zinc	Risks to individual birds are present and population-level risks may be present
Note: <sup>1</sup> Risk to individuals of characterized as negligible are not included in this table.			

Baseline risks to ecological receptors associated with the wastes in the impoundments north of I-10 are the result of exposures to dioxins localized to the immediate vicinity of the impoundments. Baseline ecological risks include reproductive risks to mollusks from dioxin, but primarily in the area that surrounds the former waste impoundments north of I-10, and low risks of reproductive effects in individual mollusks in sediments adjacent to the sand separation area, but not to populations of mollusks. Baseline risks include moderate risks to individual birds like the killdeer or spotted sandpiper whose foraging area could regularly include the shoreline adjacent to the impoundments north of I-10, but low risk to populations because of the low to moderate probability that individual exposures reach effects levels. Baseline risks include risks to individual small mammals with home ranges that include areas adjacent to the impoundments such as the marsh rice rat, but low to negligible risks to small mammal populations because of the moderate probability that exposures will reach levels associated with reproductive effects in individuals, and because small mammals reproduce rapidly. Baseline risks to benthic macroinvertebrate communities and populations of fish, birds, mammals, and reptiles resulting

from the presence of metals, bis(2-ethylhexyl) phthalate, Polychlorinated Bi-Phenyls, carbazole, and phenol on the Site are negligible. Risks to fish populations from all chemicals of potential concern are negligible.

There are negligible risks to populations of wading birds represented by the great blue heron, and to populations of diving birds like the neotropic cormorant. There are negligible risks to populations of terrestrial mammals such as the raccoon. There are low to negligible risks to individual terrestrial insectivorous birds like the killdeer from exposure to zinc, and negligible risks to populations of such birds. Although the upper bound of estimated daily intakes of zinc by individual killdeer is about equal to conservative effects thresholds, the exposure estimate is influenced by the use of generic models to estimate zinc concentrations in the foods of the killdeer, and this model likely overestimates ingested tissue concentrations, resulting in overestimates of exposure and risk. The highest exposures of killdeer to zinc occur outside of the northern impoundment perimeter, and background exposures less than 30 percent were lower than on the Site. In addition, the low probability of individual exposures exceeding effects levels indicates low risk to populations. There are also low to negligible risks to individual terrestrial insect eating birds from exposure to dioxins. The ecological risk assessments identified risk to ecological receptors as summarized in the tables below.

### **2.7.3 Basis for Action**

In summary, the site poses unacceptable risks to the recreational fisher (Hazard Index 65), to the recreational visitor (Hazard Index 66), and, for the southern impoundment, to the construction worker (Hazard Index 46). These risks result from release or threatened releases of dioxins, furans, and PCBs from the site.

The response action selected in this ROD is necessary to protect the public health or welfare and the environment from actual or threatened releases of hazardous substances, as defined by NCP §300.5, into the environment.

## **2.8 REMEDIAL ACTION OBJECTIVES**

Remedial Action Objectives (RAOs) describe what the proposed site cleanup is expected to accomplish. According to the NCP, 40 CFR §300.430(a)(1)(i), the “national goal of the remedy selection process is to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste.” Based on information relating to types of contaminants, environmental media of concern, and potential exposure pathways, site specific RAOs were developed. The remedial action objectives developed consider the current and reasonably anticipated future land use including the use for industrial applications and by recreational fishers. Concentrations of polychlorinated bi-phenyls in waste materials and sediments were either significantly correlated with concentrations of dioxins or were generally below detection limits. Therefore, no remedial action objective was developed for polychlorinated bi-phenyls because remediation of material contaminated with dioxins will also remediate the co-located polychlorinated bi-phenyls. While the human health risk assessment considered subsistence fisher populations, the Texas Department of State and Health Services (DSHS) could not identify subsistence fishers in the area of the site. Therefore, this receptor is not considered to be consistent with the current or future land use. The Environmental Protection

Agency used the next most conservative value of a child recreational fisher for its risk calculations.

The Remedial Action Objectives are:

- RAO 1: Prevent releases of dioxins and furans above protective levels from the former waste impoundments to sediments and surface water of the San Jacinto River.
- RAO 2: Reduce human exposure to dioxins and furans from ingestion of fish by remediating sediments to appropriate cleanup levels.
- RAO 3: Reduce human exposure to dioxins and furans from direct contact with or ingestion of paper mill waste, soil, and sediment by remediating affected media to appropriate cleanup levels.
- RAO 4: Reduce exposures of benthic invertebrates, birds, and mammals to paper mill waste derived dioxins and furans by remediating affected media to appropriate cleanup levels.

The following cleanup levels provide numerical criteria that will be used to measure the progress in meeting the Remedial Action Objectives. The cleanup levels are acceptable exposure levels (i.e., contaminant concentration levels) that are protective of human health and the environment, and are developed considering applicable or relevant and appropriate requirements, as specified in the National Contingency Plan.

Site risk-based cleanup levels are presented below:

- Dioxin in sediment – 30 ng/kg (recreational fisher). This level is also protective for ecological risk.
- Dioxin in paper mill waste material and soil in the Northern Impoundments – 30 ng/kg (recreational fisher).
- Dioxin in paper mill waste material and soil in the Southern Impoundment – 240 ng/kg (Southern Impoundment construction worker).
- Texas Surface Water Quality Standard for Dioxins/Furans –  $7.97 \times 10^{-8}$  µg/L (as TCDD equivalents). [30 Texas Administrative Code §307.6(d)(a)(A) and (B) and §307.10]. This standard was updated by the Texas Commission on Environmental Quality in 2014 and approved by the Environmental Protection Agency to base the dioxin standard on water column criteria. The standard was calculated based on an oral cancer slope factor of 156,000 found in the Environmental Protection Agency 2002 National Recommended Water Quality Criteria Matrix.

The sediment cleanup level of 30 ng/kg was developed for the Site based on protecting human health of the most vulnerable potentially exposed group or individual of the community. In this

case a recreational child fisher was assumed to get exposed to contaminated sediment through incidental ingestion, dermal contact, and from the ingestion of fish/shellfish. The 30 ng/kg is associated with a noncancer Hazard Index of one with the understanding that protection at a Hazard Index of one will also protect for cancer effects near the middle ( $2.1 \times 10^{-5}$ ) of the Environmental Protection Agency's generally acceptable cancer risk range.

The 240 ng/kg cleanup level applies to waste material and sub-surface soil for the Southern Impoundment (Figure 335) and is associated with a non-cancer Hazard Index of one. In this case a construction worker was assumed to get exposed to contaminated sub-surface soils in the area during construction activities.

The background sediment reference envelope value upstream from the Site has a dioxin concentration of 7.2 ng/kg, which is well below the sediment cleanup level of 30 ng/kg. Therefore, re-contamination of the Site by new sediment being carried downstream is not likely. There are no cleanup level for fish tissue because the required sediment cleanup measures at the site will reduce contaminant concentrations in tissue, but these concentrations will continue to be affected by factors outside the scope of the Comprehensive Environmental Response, Compensation, and Liability Act site cleanup, including upstream and downstream dioxin inputs from other sources. Measuring trends against target tissue concentrations is useful for assessing risk reduction and for risk communication, but tissue cleanup levels are not required to evaluate these trends. It is anticipated that the 30 ng/kg dioxin cleanup level in sediment will be achieved relatively soon after construction of the Preferred Alternative (Alternative 6N) is completed, or approximately 2½ years after construction begins. The 240 ng/kg dioxin cleanup level for the Southern Impoundment will be achieved when construction of the Preferred Alternative there (Alternative 4S) is completed, or approximately 7 months after construction begins.

The cleanup level for sediment (30 ng/kg) is based upon risk concerns. Figure 34 does show sediment areas that are greater than the cleanup level of 30 ng/kg. However, when considering the overall Site, the average surface sediment concentration, at 16.1 ng/kg, is significantly less than the cleanup level of 30 ng/kg. This assessment of the weighted average sediment concentration outside of the impoundments is reasonable and consistent with the risk assessment. Notwithstanding the previous statements, the sediment in the Sand Separation Area will be addressed under the remedial alternatives discussed below, with the exception of the no further action alternative.

## **2.9 DESCRIPTION OF ALTERNATIVES**

The feasibility study identified and screened possible response actions and remedial technologies applicable to the site. Several treatment technologies, including thermal (in-pile thermal desorption) and chemical (solvated electron technology and base catalyzed decomposition) processes, were also considered for use at the site but were not included in a remedial alternative, as discussed further in the Feasibility Study. The feasibility study contains a detailed analysis of each alternative against the remedy selection criteria and a comparative analysis of how the alternatives compare to each other.

Following the screening process, remedial alternatives were developed to address the area north of I-10 and the area south of I-10. Alternatives that address the area north of I-10 and aquatic

environment include the letter “N” in the title (e.g., 1N, 2N), and alternatives that address the area south of I-10 include the letter “S” in the title (e.g., 1S, 2S). During the Feasibility Study, cost estimates were developed for each remedial action alternative for comparison purposes. The expected accuracy of Feasibility Study cost estimates ranges from –30 percent to +50 percent. The EPA developed additional cost information in the process of responding to public comments. The total present worth costs for this and all other alternatives are calculated using a 30-year timeframe and a 7% discount rate.

## **Alternatives for the San Jacinto River and Area North of I-10:**

### ***Alternative 1N – Temporary Armored Cap and Ongoing Operations, Inspection, and Maintenance (No Further Action)***

*Estimated Maintenance Cost (e.g., inspection, maintenance): \$0.4 million*

*Estimated Total Present Worth Cost: \$0.4 million*

*Estimated Construction Time/Time to meet RAOs: Construction complete*

Under this alternative, No Further Action would be conducted for the temporary armored cap constructed under the Time Critical Removal Action, and no additional remedial action would be implemented. Treatment through solidification of a portion (6,000 cubic yards) of the paper mill waste material was completed to aid construction of the cap. However, this alternative has no further provision for treatment or removal of the Principal Threat Waste. This alternative includes ongoing operations, inspection, and maintenance of the armored cap, which includes inspection and periodic maintenance. This alternative has no provision for the sand separation area. This alternative will not comply with all of the Applicable or Relevant and Appropriate Requirement (ARARs) for the Site.

### ***Alternative 2N – Armored Cap, Institutional Controls, Ground Water Monitoring, and Monitored Natural Recovery***

*Estimated Maintenance Cost: \$2.0 million*

*Estimated Total Present Worth Cost: \$2.0 million*

*Estimated Construction Time/Time to meet RAOs: Construction complete*

This alternative includes all of the elements discussed under Alternative 1N, plus institutional and engineering controls, ground water monitoring, and Monitored Natural Recovery. Monitored Natural Recovery would be used to achieve the cleanup level for sediment in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River. Hydrodynamic and sediment transport modeling of the San Jacinto River in the vicinity of the Site determined that there is a net deposition of sediment that will support Monitored Natural Recovery. Further, approximately two feet of sediment deposition found in deeper areas over the toe of the cap in the northwest area during an Environmental Protection Agency Dive Team inspection of the cap supports the depositional nature of some areas. However, riverbed erosion/scour has also occurred in some areas as demonstrated by the 2015 and the 2017 flooding when eroded areas were discovered adjacent to the eastern part of the temporary cap. Because future sedimentation is uncertain, monitoring will be conducted to assess natural recovery. This Alternative 2N this

would not result in treatment of the Principal Threat Waste other than the solidification for the original construction of the cap.

Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place. Groundwater monitoring will be conducted in areas bounding waste materials (both vertically and laterally) and will include both dissolved phase COC concentrations and concentrations that may result from facilitated transport. Institutional controls are non-engineered instruments such as administrative and legal controls that help minimize the potential for human exposure to contamination and protect the integrity of a remedy by limiting land or resource use. Engineering controls are physical measures such as fencing or signage that are used to limit access to contaminated areas or areas that may pose a physical hazard. Institutional controls would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the sand separation area. Under this remedial alternative, the following institutional and engineering controls would be implemented:

- A special sampling and analysis protocol will be required for each permittee conducting activities under the Clean Water Act Section 404 and Rivers and Harbors Action Section 10 within a defined watershed area around the remediated areas. This protocol will be monitored and enforced by a joint EPA, USACE, and TCEQ agreement and will ensure that permitted dredging activities do not impact site cleanup. These restrictions will protect the integrity of the armored cap and sand separation area and limit potential disturbance and resuspension of buried sediment.
- Alert property owners of the presence of subsurface materials exceeding cleanup levels.
- Public notices and signage around the perimeter of the armored cap site would be maintained or provided, as appropriate.
- As a result of the long term persistence of dioxin, it is anticipated that the institutional controls will be essentially permanent measures.

This alternative includes ongoing operations, inspection, and maintenance of the armored cap, which includes inspection and periodic maintenance, and the Environmental Protection Agency 5-year reviews as required under the National Contingency Plan in 40 Code of Federal Regulations 300.430 (f)(iv)(2). A periodic sampling and analytical program would also be implemented to monitor the progress of natural recovery. The current temporary cap has had no impact on navigation, and this alternative is not expected to be different.

***Alternative 3N – Upgraded Cap, Institutional Controls, Ground Water Monitoring, and Monitored Natural Recovery***

*Estimated Capital Cost: \$1.77 million*

*Estimated In-Direct and Operation & Maintenance Cost: \$2.38 million*

*Estimated Total Present Worth Cost: \$4.1 million*

*Estimated Construction Time/Time to meet RAOs: 2 months*

This alternative includes the actions described under Alternative 2N plus additional improvements to the temporary armored cap to create an upgraded cap. The improvements use a higher factor of safety of 1.5 for sizing the armor stone, and include flattening submerged slopes from 2-horizontal to 1-vertical (2H:1V) to 3H:1V and flattening the slopes in the surf zone from 3H:1V to 5-horizontal to 1-vertical (5H:1V). In addition, the Upgraded Cap uses larger rock sized for the “No Displacement” design scenario, which is more conservative than the “Minor Displacement” scenario used in the Armored Cap’s design. This alternative will increase the long-term stability of the armored cap compared to Alternatives 1N and 2N. However, the upgraded cap under Alternative 3N is expected to experience 80% erosion of the cap during a severe storm as modelled by the Corps of Engineers and documented in the Corps’ report (Appendix A of the Feasibility Study). Cost estimates for this alternative also include additional measures to protect the upgraded cap from potential vessel traffic in the form of a protective perimeter barrier and could include construction of a 5-foot high submerged rock berm outside the perimeter of the upgraded cap, in areas where vessels could potentially impact the cap. Monitored Natural Recovery would be used to achieve the cleanup level for sediment in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

This Alternative 3N would not result in treatment other than the previously performed solidification for construction of a portion of the Principal Threat Waste, which is defined as material containing dioxin greater than 300 ng/kg.

Upon completion, the Upgraded Cap would be constructed to a standard that exceeds Environmental Protection Agency and United States Army Corps of Engineers design guidance, and meets or exceeds the recommended enhancements suggested by the United States Army Corps of Engineers in their 2013 evaluation. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place. Groundwater monitoring will be conducted in areas bounding waste materials (both vertically and laterally) and will include both dissolved phase COC concentrations and concentrations that may result from facilitated transport. Institutional controls would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the sand separation area. Under this remedial alternative, the following institutional and engineering controls would be implemented:

- A special sampling and analysis protocol will be required for each permittee conducting activities under the Clean Water Act Section 404 and Rivers and Harbors Action Section 10 within a defined watershed area around the remediated areas. This protocol will be monitored and enforced by a joint EPA, USACE, and TCEQ agreement and will ensure that permitted dredging activities do not impact site cleanup. These restrictions will
- protect the integrity of the armored cap and sand separation area and limit potential disturbance and resuspension of buried sediment. Alert property owners of the presence of subsurface materials exceeding cleanup levels.
- Public notices and signage around the perimeter of the armored cap site would be maintained or provided, as appropriate.
- As a result of the long term persistence of dioxin, it is anticipated that the institutional controls will be essentially permanent measures.<sup>404</sup>

This alternative includes ongoing operations, inspection, and maintenance of the armored cap, which includes inspection and periodic maintenance, and the Environmental Protection Agency 5-year reviews as required under the National Contingency Plan in 40 Code of Federal Regulations 300.430 (f)(iv)(2). A periodic sampling and analytical program would also be implemented to monitor the progress of natural recovery. The current temporary cap has had no impact on navigation, and this alternative is not expected to be different.

***Alternative 3aN – Enhanced Cap, Protective Pilings, Institutional Controls, Ground Water Monitoring, and Monitored Natural Recovery***

*Estimated Capital Cost: \$19.7 million*

*Estimated In-Direct and Operation & Maintenance Cost: \$5.1 million*

*Estimated Total Present Worth Cost: \$24.8 million*

*Estimated Construction Time/Time to meet RAOs: 15 months*

The Corps of Engineers determined that the cap considered for Alternative 3N may experience 80% erosion of the armor cap (Appendix A of the Feasibility Study), and substantial erosion of the underlying paper mill waste material in a future severe storm. This alternative, 3aN, includes the actions described under Alternative 3N plus additional enhancements to the armored cap recommended by the Corps of Engineers to create an enhanced cap with increased long-term stability.

The additional cap enhancements added for this alternative include pre-stressed concrete or concrete filled steel pipe pilings placed 30 feet apart around the perimeter of the cap to protect from barge strikes. The spacing is designed to catch a typical barge, which is 35 feet wide. An additional armor stone cap with a thickness of at least 24 inches would be placed over the armor cap for Alternative 3N. The armor stone would have a median diameter of 15 inches. This additional armor stone would cover 13.4 acres of the 17.1-acre armored cap. Also, a coarse gravel filter layer would be placed on 1.5 acres of the Northwest Area where there is currently no geotextile under the armor cap. The actual scope and design of the cap enhancements, and additional area needed to construct the required slopes, would be determined in the Remedial Design. This additional weight of rock on top of the waste pits may cause cap settling and/or pushing the waste material out the sides of the cap; the Remedial Design will consider the significance of and design issues related to this. Monitored Natural Recovery would be used to achieve the cleanup level for sediment in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

This Alternative 3aN this would not result in treatment of the Principal Threat Waste, which is defined as site material containing dioxin greater than 300 ng/kg, with the exception of the solidification for construction of the western cell of the original cap. Alternative 3aN also would require ongoing maintenance to ensure cap integrity over the hundreds of years the site waste will remain toxic.

Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place. Groundwater

monitoring will be conducted in areas bounding waste materials (both vertically and laterally) and will include both dissolved phase COC concentrations and concentrations that may result from facilitated transport. Institutional controls would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the sand separation area. Under this remedial alternative, the following institutional and engineering controls would be implemented:

- A special sampling and analysis protocol will be required for each permittee conducting activities under the Clean Water Act Section 404 and Rivers and Harbors Action Section 10 within a defined watershed area around the remediated areas. This protocol will be monitored and enforced by a joint EPA, USACE, and TCEQ agreement and will ensure that permitted dredging activities do not impact site cleanup. These restrictions will
- protect the integrity of the armored cap and sand separation area and limit potential disturbance and resuspension of buried sediment. Alert property owners of the presence of subsurface materials exceeding cleanup levels.
- Public notices and signage around the perimeter of the armored cap site would be maintained or provided, as appropriate.
- As a result of the long term persistence of dioxin, it is anticipated that the institutional controls will be essentially permanent measures.

This alternative includes ongoing operations, inspection, and maintenance of the armored cap, which includes inspection and periodic maintenance, and the Environmental Protection Agency 5-year reviews as required under the National Contingency Plan in 40 Code of Federal Regulations 300.430 (f)(iv)(2). A periodic sampling and analytical program would also be implemented to monitor the progress of natural recovery. The current temporary cap has had no impact on navigation, and this alternative is not expected to be different.

***Alternative 4N – Partial Solidification/Stabilization, Upgraded Cap, Institutional Controls, Ground Water Monitoring, and Monitored Natural Recovery***

*Estimated Capital Cost: \$11.1 million*

*Estimated In-Direct and Operation & Maintenance Cost: \$3.7 million*

*Estimated Total Present Worth Cost: \$14.8 million*

*Estimated Construction Time/Time to meet RAOs: 17 months*

This remedial alternative provides for solidification and stabilization of the most highly contaminated material. The purpose of solidification/stabilization at the site is to reduce the mobility of the waste material, thereby reducing the potential for a dioxin release into the San Jacinto River. A dioxin and furan value that exceeds 13,000 ng/kg dioxin was used to define the most highly contaminated material. This alternative would result in treatment of a portion of the Principal Threat Waste. Under this alternative, 3.6 acres of the armor cap would be removed and about 52,000 cubic yards of materials beneath the cap exceeding 13,000 ng/kg dioxin regardless of waste material depth would undergo solidification and stabilization. The type of amendments would be determined during the Remedial Design. The extent of the area for partial solidification and stabilization is the western cell and a portion of the eastern cell that is currently covered by the armored cap. Based on current site data, all samples exceeding 13,000 ng/kg dioxin are

located in areas where the water depth is 10 feet or less, so the maximum depth of solidification and stabilization in the western cell would be to approximately 10-feet below the current base of the armored cap and on average approximately 5-feet below the current base of the armored cap in the eastern cell and northwestern area.

For solidification/stabilization, amendments such as Portland cement or other materials would be mixed with the waste material. Mixing of amendments and the waste material could be accomplished using large diameter augers or conventional excavators. Before mixing, portions of the armored cap armor rock where mixing will occur would need to be removed and stockpiled for reuse, if possible, or washed to remove adhering sediment and disposed in an appropriate facility. The geotextile and geomembrane in those areas would also need to be removed and disposed of as contaminated debris. Submerged areas to be stabilized would need to be isolated from the surface water with sheet piling and mostly dewatered prior to mixing with treatment reagents using conventional or long reach excavators.

Finally, an upgraded cap would be constructed as described in 3N, including replacement of the armor rock layer geomembrane and geotextile over the solidification and stabilization footprint; and the measures described under Alternative 3N to protect the upgraded cap from vessel traffic would be implemented.

Monitored Natural Recovery would be used to achieve the sediment cleanup level in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River. Institutional controls would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the sand separation area. Under this remedial alternative, the following institutional and engineering controls would be implemented:

- A special sampling and analysis protocol will be required for each permittee conducting activities under the Clean Water Act Section 404 and Rivers and Harbors Action Section 10 within a defined watershed area around the remediated areas. This protocol will be monitored and enforced by a joint EPA, USACE, and TCEQ agreement and will ensure that permitted dredging activities do not impact site cleanup. These restrictions will
- protect the integrity of the armored cap and sand separation area and limit potential disturbance and resuspension of buried sediment.
- Alert property owners of the presence of subsurface materials exceeding cleanup levels.
- Public notices and signage around the perimeter of the armored cap site would be maintained or provided, as appropriate.
- As a result of the long term persistence of dioxin, it is anticipated that the institutional controls will be essentially permanent measures.

Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place. Groundwater monitoring will be conducted in areas bounding waste materials (both vertically and laterally) and will include both dissolved phase COC concentrations and concentrations that may result from facilitated transport.

The estimated footprint of this alternative is approximately 2.6 acres in the western cell and 1.0 acre of submerged waste material spanning the eastern cell and the northwestern area. Based on the horizontal and vertical limits identified for this alternative, a total of approximately 52,000 cubic yards of soil and waste material would be treated.

This alternative includes ongoing operations, inspection, and maintenance of the armored cap, which includes inspection and periodic maintenance, and the Environmental Protection Agency 5-year reviews as required under the National Contingency Plan in 40 Code of Federal Regulations 300.430 (f)(iv)(2). A periodic sampling and analytical program would also be implemented to monitor the progress of natural recovery. The current temporary cap has had no impact on navigation, and this alternative is not expected to be different.

***Alternative 5N – Partial Removal, Upgraded Cap, Institutional Controls, Ground Water Monitoring, and Monitored Natural Recovery***

*Estimated Capital Cost: \$24.86 million*

*Estimated In-Direct and Operation & Maintenance Cost: \$4.94 million*

*Estimated Total Present Worth Cost: \$29.8 million*

*Estimated Construction Time/Time to meet RAOs: 13 months*

This remedial alternative provides for removal and offsite disposal of the most highly contaminated material. A dioxin and furan value that exceeds 13,000 ng/kg dioxin was used to define the most highly contaminated material; however, this would not result in removal or treatment of all of the Principal Threat Waste, which is defined as site material containing dioxin greater than 300 ng/kg. Under this alternative, 3.6 acres of the armor cap would be removed and about 52,000 cubic yards of materials beneath the cap exceeding 13,000 ng/kg dioxin, regardless of waste material depth, would be removed. The lateral and vertical extent and volume of waste material removed under this alternative is the same as the waste material to be treated as described in the previous section for alternative 4N. Construction of an upgraded cap, institutional controls, and Monitored Natural Recovery for the sand separation area, as described in Alternative 3N, are also included in this remedial alternative.

To mitigate potential water quality issues, submerged areas would need to be isolated using berms, sheet piles, and/or turbidity barrier/silt curtains prior to excavating waste material. Upland areas would not need to be isolated with sheet piling, but the excavation would require continuous dewatering and may need to be timed to try to avoid high water and times of year when storms are most likely.

Treatability studies will be conducted during the Remedial Design to determine the appropriate type and amount of stabilization amendments to treat the waste materials and meet the disposal standards of the receiving facility. The agents for stabilization may include fly ash, cement, soil, or other materials. The material removed during the remediation will be tested to comply with the applicable requirements. Effluent from excavated waste material dewatering would need to be handled appropriately, potentially including treatment prior to disposal. Following completion of the excavation, the work area would be backfilled to replace the excavated waste material and then the upgraded cap would be constructed, including replacing the armor rock layer above the

excavation footprint and the geomembrane and geotextile layers. Institutional controls would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the sand separation area. Under this remedial alternative, the following institutional and engineering controls would be implemented:

- A special sampling and analysis protocol will be required for each permittee conducting activities under the Clean Water Act Section 404 and Rivers and Harbors Action Section 10 within a defined watershed area around the remediated areas. This protocol will be monitored and enforced by a joint EPA, USACE, and TCEQ agreement and will ensure that permitted dredging activities do not impact site cleanup. These restrictions will
- protect the integrity of the armored cap and sand separation area and limit potential disturbance and resuspension of buried sediment.
- Alert property owners of the presence of subsurface materials exceeding cleanup levels.
- Public notices and signage around the perimeter of the armored cap site would be maintained or provided, as appropriate.
- As a result of the long term persistence of dioxin, it is anticipated that the institutional controls will be essentially permanent measures.

Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place. Groundwater monitoring will be conducted in areas bounding waste materials (both vertically and laterally) and will include both dissolved phase COC concentrations and concentrations that may result from facilitated transport.

This alternative includes ongoing operations, inspection, and maintenance of the armored cap, which includes inspection and periodic maintenance, and the Environmental Protection Agency 5-year reviews as required under the National Contingency Plan in 40 Code of Federal Regulations 300.430 (f)(iv)(2). A periodic sampling and analytical program would also be implemented to monitor the progress of natural recovery. The current temporary cap has had no impact on navigation, and this alternative is not expected to be different.

***Alternative 5aN - Partial Removal, Upgraded Cap, Institutional Controls, Ground Water Monitoring, and Monitored Natural Recovery***

*Estimated Capital Cost: \$60.38 million*

*Estimated In-Direct and Operation & Maintenance Cost: \$9.21 million*

*Estimated Total Present Worth Cost: \$69.6 million*

*Estimated Construction Time/Time to meet RAOs: 19 months*

For this alternative, the original cleanup level for a recreational visitor of 200 ng/kg dioxin was considered for the areas within the armored cap, which are either above the water or where the water depth is 10 feet or less. As an additional criterion for this alternative, locations exceeding 13,000 ng/kg dioxin are also removed regardless of water depth; however, all samples exceeding 13,000 ng/kg dioxin are located in areas where the water depth is 10 feet or less. This alternative entails removal of approximately 137,600 cubic yards of waste material from the waste pits.

As with Alternatives 4N and 5N, the existing armored cap (consisting of cap rock, geomembrane, and geotextile) would need to be removed prior to beginning excavation work.

This alternative also includes an engineered barrier to manage water quality during construction. In shallow water areas (water depths up to approximately 3 feet), this barrier would be constructed as an earthen berm, extending to an elevation at least 2 feet above the high water elevation in consideration of wind generated waves and vessel wakes.

Submerged areas would need to be isolated using berms, sheet piles, and/or turbidity barrier/silt curtains prior to excavating waste material. Excavated waste material would be offloaded, dewatered, and stabilized at a dedicated offloading location, as necessary, to eliminate free liquids for transportation and disposal.

Following removal of impacted waste material, the area from which waste materials are removed would be covered with a residuals management layer of clean cover material.

Treatability studies will be conducted during the Remedial Design to determine the appropriate type and amount of stabilization amendments to treat the waste materials and meet the disposal standards of the receiving facility. The agents for stabilization may include fly ash, cement, soil, or other materials. The material removed during the remediation will be tested to comply with the applicable requirements

In the deeper water areas of the waste pits where removal is not conducted, the existing armored cap would be maintained. Monitored Natural Recovery would be used to achieve the cleanup level for sediment in the sand separation area. Institutional controls would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried waste material near the sand separation area. Under this remedial alternative, the following institutional and engineering controls would be implemented:

- A special sampling and analysis protocol will be required for each permittee conducting activities under the Clean Water Act Section 404 and Rivers and Harbors Action Section 10 within a defined watershed area around the remediated areas. This protocol will be monitored and enforced by a joint EPA, USACE, and TCEQ agreement and will ensure that permitted dredging activities do not impact site cleanup. These restrictions will
- protect the integrity of the armored cap and sand separation area and limit potential disturbance and resuspension of buried sediment. Alert property owners of the presence of subsurface materials exceeding cleanup levels.
- Public notices and signage around the perimeter of the armored cap site would be maintained or provided, as appropriate.
- As a result of the long term persistence of dioxin, it is anticipated that the institutional controls will be essentially permanent measures.

Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place. Groundwater

monitoring will be conducted in areas bounding waste materials (both vertically and laterally) and will include both dissolved phase COC concentrations and concentrations that may result from facilitated transport.

This alternative includes ongoing operations, inspection, and maintenance of the armored cap, which includes inspection and periodic maintenance, and the Environmental Protection Agency 5-year reviews as required under the National Contingency Plan in 40 Code of Federal Regulations 300.430 (f)(iv)(2). A periodic sampling and analytical program would also be implemented to monitor the progress of natural recovery. The current temporary cap has had no impact on navigation, and this alternative is not expected to be different.

***Alternative 6N - Removal of Waste Materials Exceeding Cleanup Levels, MNR, and Institutional Controls***

*Estimated Capital Cost: \$ 93.7 million*

*Estimated In-Direct and Operation & Maintenance Cost: \$11.8 million*

*Estimated Total Present Worth Cost: \$ 105 million*

*Estimated Construction Time/Time to meet RAOs: 27 months*

This alternative involves the removal of all waste material that exceeds the cleanup level of 30 ng/kg regardless of depth in the northern waste pits. As discussed in the Proposed Plan of Action, EPA and USACE indicated that a potential small release of the waste material may occur during removal activities under alternative 6N. Comments received during the Proposed Plan comment period requested that EPA consider the use of additional Best Management Practices (BMPs) to prevent or minimize the release of waste material during removal. To this end, the EPA worked with USACE to further evaluate the use of BMPs to minimize releases during remedial action. One of the BMPs proposed was the use of a cofferdam with excavation in the “dry” to prevent the re-suspension and residuals that typically result from under water dredging. It should be noted that the actual BMPs to be utilized will be determined during the Remedial Design phase after engineering assessment and evaluation. All final BMPs used as part of the remedial action will have to comply with ARARs, including the requirement that there be no discharges that exceed the Texas Surface Water Quality Standards. Monitored Natural Recovery (MNR) will be used for the sediment in the sand separation area. This alternative would involve removal of the majority of the existing armored cap and the removal of 162,000 cubic yards of material.

Treatability studies will be conducted during the Remedial Design to determine the appropriate type and amount of stabilization amendments to treat the waste materials and meet the disposal standards of the receiving facility. The agents for stabilization may include fly ash, cement, soil, or other materials. The material removed during the remediation will be tested to comply with the applicable requirements. Some operations, such as water treatment, may be barge mounted.

This alternative entails removal of approximately 162,000 cubic yards of waste material from the waste pits footprint, which would require an offloading and waste material processing facility to efficiently accomplish the work. Additional activities would include management and disposal of dewatering effluent, including treatment if necessary. Material that is removed would be transported in compliance with applicable requirements and permanently managed in an